Corrosion

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CORROSION CONTROL
PROTECTED INDUSTRY
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

OFFICIAL PUBLICATION
NATIONAL ASSOCIATION
OF
CORROSION ENGINEERS

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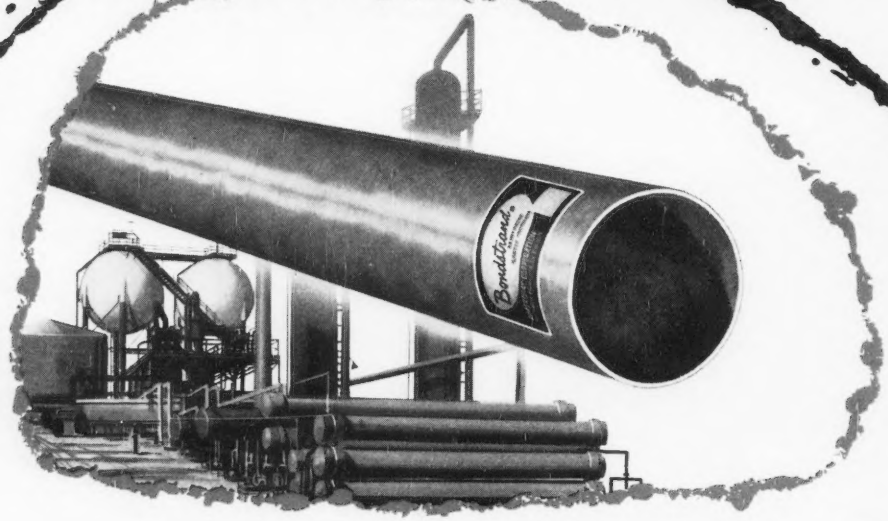

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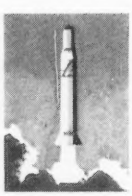

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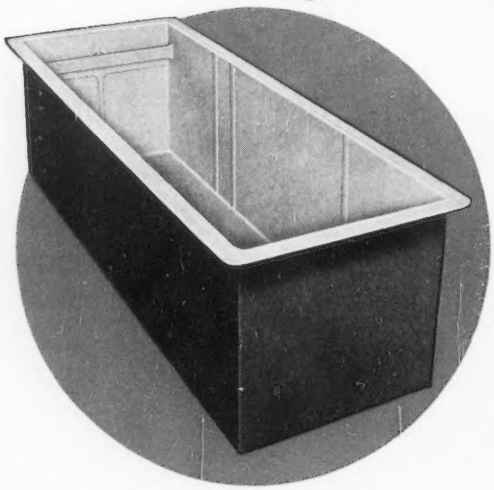

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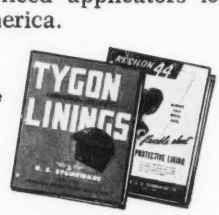

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This Month in Corrosion Control . . .

CREVICES AND CORNERS were prime culprits in the corrosion damage suffered by a fly-ash flue-gas scrubber. Salt removed from the effluent was concentrated during the paper making process from that absorbed by logs transported to the mill via salt water. See Page 9.

SHIPBOTTOM COATINGS' reactions to cathodic protection currents from one to six volts over periods up to 22 months are reported in an article beginning on Page 12. The growing number of cathodic protection installations on ship hulls makes these data especially interesting. Thirty primers, coatings, formulations or anti-fouling paints are rated.

ALUMINUM'S growing use in oil refinery applications is reviewed in an article beginning on Page 16. Advantage of using this light-weight metal in many applications is explained. There are 24 literature references and a number of penetrating questions and answers in the discussion.

POLYVINYL DICHLORIDE PLASTIC that withstands high temperatures (better than conventional vinyl, high density polyethylene and polyamides) performed well in 90 percent sulfuric acid at 185 F for 30 days. It is good for pressures up to 150 psi, the manufacturer reports in an item on Page 30.

STATISTICS ON CORROSION losses and a discussion of the economics of corrosion is included in an interesting "Letter to the Editor" beginning on Page 52. The author tells how some of the compartmented thinking in industry is conducive to waste.

FOUR SHORT COURSES on corrosion-control will be held during 1961 in various parts of the nation. Preliminary information on these courses in which NACE cooperates will be found on Page 39.

CATHODIC PROTECTION progress using inert anodes for impressed current systems is reviewed from 1928 to date in an article starting on Page 79. This discussion, which reviews some of the old and new concepts concerning these systems, also gives fundamental information about calculating the resistances of ground beds with multiple anodes.

MATERIALS SELECTION for refinery and petrochemical service at high temperatures is considered in a well-organized paper beginning on Page 85. Anyone who has the responsibility for selecting materials for service in these environments will find this survey useful. The 32 references lead into detail expositions of the subjects covered.

WELDS and the surfaces adjoining them often are the first areas in a painting system to deteriorate. How these failures may be minimized or avoided entirely is explained by two engineers who have worked years on painting problems. Turn to Page 93 for a report on tests which involve the principal variables in weld coating. Thirteen tables and 14 references.

NICKEL-CHROMIUM ALLOYS exposed to carbon monoxide type atmospheres at high temperatures internally carburize and oxidize at maximum rate at temperatures in the 1500-1750 F range. Influence of carbon dioxide, moisture, hydrogen and mixtures is explored. The beneficial influence of silicon is reported. See Page 100.

STREET DE-ICING SALT concentrations in Buffalo, N.Y. manhole water are given in a report by NACE T-4D Committee on Corrosion by De-Icing Salts. Turn to Page 105 for data covering 3½ years.

GLASS LININGS and vitreous enamels are exhaustively considered in a report by NACE Technical Committee 6H on Glass Linings and Vitreous Enamels beginning on Page 107. The report reviews types of glass, preparation for production, application, metal surface preparation, hydrogen absorption, handling equipment, glassed pipe, gasketing, thermal shock and resistance to several commonly found acids and alkalis. This authoritive report should be valuable to any company using or planning to use this material.

INDEXING as thorough as that done on CORROSION's technical articles is rare. Persons concerned with scientific and technical data on corrosion control published in CORROSION during 1960 will find this year's index a time-saver. Included are 12 months' tables of contents, an alphabetical subject index carefully and conscientiously made after a page-by-page analysis of the technical information and an alphabetical list of 294 authors.

LIBRARIANS and others who bind CORROSION for permanent filing are notified again that the indexing this year includes the articles published in Technical Topics Section. For a bound volume to match the index it will be necessary to extract these articles (which are not consecutively numbered) and include them with the pages from the Technical Section.

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New Developments Lead to Easier Retrieval of Data

BECAUSE OF RAPID progress being made in electrical and other methods of locating technical data, the outlook for its better use is improving. This progress is accelerating. Some of the more recent advances may be considered breakthroughs in the constant battle being waged to keep up with events.

Among the more significant advances in recent months are:

1. The fruition of American Society for Metals' electronic storage and searching program. Service from this system is now being offered.

2. American Chemical Society's *Chemical Titles* magazine in which titles of technical articles are repeated several times with a different indicative word emphasized in each repetition.(1)

3. The pending publication of *Current Contents of Space and Physical Sciences,* a periodical in which the contents pages of the world's principal technical journals will be reproduced. First issue is scheduled in January.(2)

4. A recent development by the Air Force in its Mark I translator, an International Business Machines device which converts Russian into English at 1800 words a minute. It has a 60,000 word dictionary representing 600,000 Russian words which will be expanded soon to 400,000 entries (4,000,000 words).(3) Devices similar to this have fine possibilities for data storage and retrieval.

These developments are important for all active in technical fields, especially corrosion workers. Because of the ubiquitous nature of corrosion, and the multiplicity of variables found in most corrosion processes, expeditious searching is especially important. Workers soon may expect to follow the tenuous threads of fact about corrosion reactions through the mazes of the literature with the assistance of these speedy electrical trackers. It begins to look as if the problem of literature search soon will be reduced to workable dimensions through the use of these publications and devices.

This says nothing about cost. It is hoped that cost will be low enough to put them in reach of most who need them. Cost of the periodicals, while several orders of magnitude greater than ordinarily paid for technical periodicals, is still within reasonable limits. As has been said before with respect to technical literature: Prevention of one mistake will save enough to pay the cost many times over.

NACE expects these developments to be beneficial in that much useful information previously unavailable because of the magnitude of the physical problem involved in search and retrieval will be reduced. They should make NACE's efforts to provide useful scientific and engineering data more fruitful. It is expected also that NACE abstracting and classification services will not be adversely affected. NACE's bibliographies will still be the best sources of quick information for the individual worker, and for the technical librarian. The large number of sources supplying the association with its abstracts is the best assurance of thorough coverage of the corrosion control field.

NACE is not standing still in the matter of abstracting and classification. The association's contribution to the total of corrosion abstract literature has grown consistently through the years until it now is more than 10 percent of the whole. While this may not seem remarkable at first glance, it becomes more significant when viewed against the fact that the 2000-odd abstracts on corrosion published each year come from some 500 periodicals. This does not take into account that much of the material published elsewhere is redundant.

The individual must learn to use the index, the bibliography, the abstract. The time is long past when one could expect to remember enough about a technical activity to function efficiently without recourse to books, reports and records. It is sufficiently difficult to remember enough to be able to search for information in an index. In any case, the minutae of the data necessary for proper decision often require ultimate precision . . . approximations seldom are sufficient. This means that the sources must be consulted.

This is an opportunity to repeat: Corrosion workers will benefit from CORROSION's indexes. The one in this issue is typical. It will save time, money and worry. If you do not have it already, get the multiple-year index of CORROSION's first ten years of publication. Get the five-year index when it is issued next spring. Use NACE's Bibliographic Surveys of CORROSION. All were prepared at great trouble and expense for the convenience and benefit of corrosion workers in all industries everywhere.

(1) *Corrosion*, September, 1960, Page 44.
(2) *Corrosion*, December, 1960, Page 24.
(3) *Saturday Review*, July 16, 1960, Page 13.

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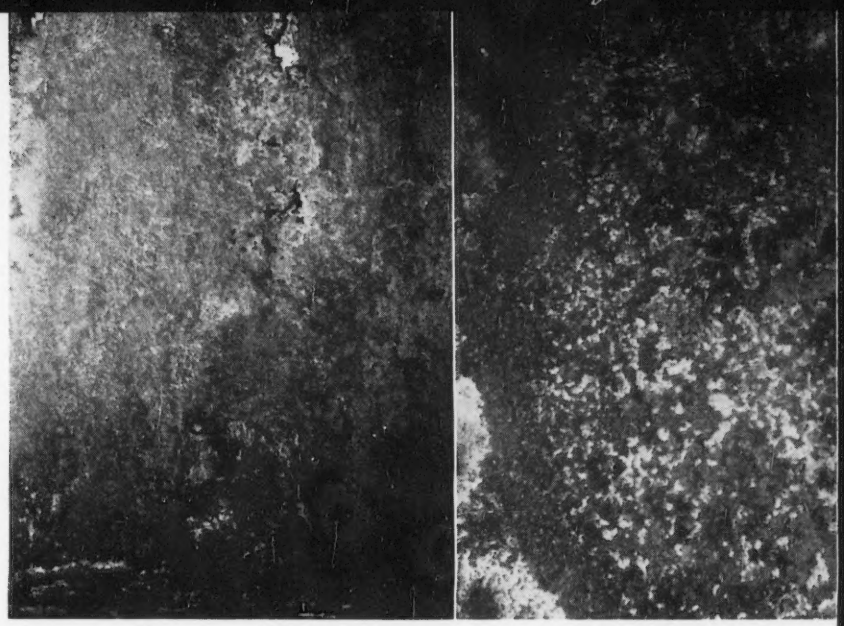
*Presented before the Society of the Plastics Industry, Feb., 1960.

In Canada: Atlas Powder Company, Canada, Ltd., Brantford, Ontario, Canada

TECHNICAL TOPICS



SALT CORROSION ATTACK on the upper flat surfaces of a gas scrubber used in a sulfate pulp mill. Scrubber was made of 12 gauge Type 316 stainless steel.

Rapid Pitting Corrosion on Gas Scrubber*

• Salt Accumulations Cause Attack Noticeable in Only 3 Weeks

J. T. Firestone

Weyerhaeuser Company
Everett, Washington

Abstract

Rapid pitting attack on stainless steel gas scrubber is described. Attack was evident in only three weeks of operation from salt accumulation on areas not washed down by water showers. Describes internal equipment and flow process of gas through scrubber. Discusses investigation for cause of corrosion and exposure tests of materials to determine suitable construction materials to solve corrosion problem. Lists materials tested. Also describes corrosive attack on internal braces. Conclusion gives five design factors that should be realized for scrubber fabrication. 3.2.2

SERIOUS PITTING occurred on a gas scrubber after only three weeks of operation in a pulp mill at Everett, Washington. Installed in 1957, the scrubber is used to remove fly ash from flue gas of a sulfate pulp recovery furnace. This scrubber operates at 90 percent efficiency in removing sodium salts before the gas is discharged in a 275-foot stack.

The scrubber is a spray nozzle (venturi throat type) in which the recovery gas passes through four banks of nozzles and throats. Made of Type 316 stainless steel, it is a box shaped structure measuring 30 feet high, 30 feet wide and 24½ feet long.

Normally, fresh water is used to supply one or two nozzle banks. The remaining nozzles are supplied with recirculated water pumped from the bottom of the scrubber. Each bank of nozzles requires 600 gallons per minute.

The rapid pitting attack in only three weeks' operation occurred in areas where fly ash from the boiler had settled and was not washed away. No corrosion was found in areas where scrubber walls were wet during normal operation. Additional wall showers were installed immediately. A ring shower using approximately 250 gallons per minute was installed at the scrubber inlet to wet gases as rapidly as possible as they entered the scrubber area. Efforts were made to spray all wall surfaces with water to keep salts from collecting. This spraying practically eliminated corrosion in the main body of the scrubber.

Investigation for Cause of Corrosion

Before construction materials can be selected or recommended for any corrosion control problem, the cause of corrosion must be investigated. A review of the operational flow process can give significant information indicating probable corrosion causes.

Furnace gases passing through the scrubber are the product of burning evaporated cooking liquor used to pulp salt-water borne logs with the kraft process. In this process, lignin and cooking chemicals are sprayed into the recovery furnace and burned. Resultant gas passes through a cyclone evaporator where 50 percent of the salts are recovered. The gas then flows through an electro-static precipitator which recovers 90 percent of the salts entering this unit.

After the precipitator, the flow goes through the scrubber and then to the stack for discharge. Gas entering the scrubber contains 187 grains of solids per cubic foot with the flowing elements: 65 percent Na_2SO_4, 18 percent NaCl, 10 percent $NaHCO_3$, 6 percent $NaCO_3$ and traces of Na_2SO_3 and SO_2.

At the scrubber entrance, there is a transition stage in which the gas changes from dry to wet. Incoming gas temperature is about 300 F in the dry state and quickly drops to 150 F when water is sprayed into the gas. This condition causes the salt to be like wet snow, adhering to wall surfaces in stagnant areas of the scrubber. This effect could not be controlled completely by showers.

Testing of Materials

A thorough check was begun of metals, coatings and adhesive films to test their resistance to corrosive attack in the scrubber. These materials were placed in the first section of the scrubber where wet salt deposits could form.

Titanium and Hastelloy C exhibited excellent resistance to the corrosive attack, but none of the materials tested showed better resistance than the Type 316 stainless used for the scrubber's fabrication. Type 316 had been selected originally because it had been used in areas successfully to resist the flue gases. Experience had proved mild steel to be unsatisfactory when exposed to the wet flue gases.

Monel, Inconel and nickel failed rapidly in the scrubber exposure, probably because of the traces of SO_2 in the gases. Chloride from the sodium chloride which originates from the salt-water borne logs is concentrated in the recovery furnace. This chloride causes failure of the stainless steels.

Experimental installations with stainless steel covered with fiberglass filled with polyester and epoxy resins are being tested. Results to date are not conclusive.

Other materials tested included Type 317 stainless, Everdur and Ni-O-Nel. Films of polytetrafluoroethylene and saturated polyesters attached with recommended adhesives were tested also, but these failed because of peeling. Several paints were tried including aluminum, epoxy coal tar, zinc filled, asphalt and various heat resistant formulations. None of these paints proved satisfactory, failing within a short time under

(Continued on Page 10)

★Revision of a paper titled "Material Evaluation for the Recovery Venturi Scrubber" presented at a meeting of the Western Division, Canadian Region, National Association of Corrosion Engineers, February 12, 1960, Vancouver, British Columbia, Canada.

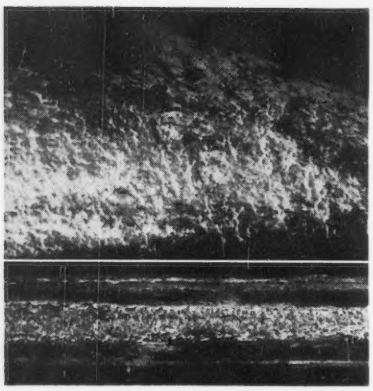


Figure 1—Corrosion attack on underside of a scrubber brace made of Type 316 stainless steel.

Pitting Corrosion—

(Continued From Page 9)

the wet salt attack. Paint type coatings seemingly could not resist the chemical, moisture and temperature conditions inside the scrubber.

Corrosion Attack on Braces

Because the scrubber was built of 12 gauge Type 316 stainless, considerable internal bracing was necessary. Bracing was formed by bending stainless steel into the most practical structural shapes such as angles and channels. These braces were used to position the baffles which hold the venturi throats and also support the shower pipes.

These shapes are such that salt collects on the underside where salts could not be washed off by the showers. Because of this salt collection, several braces were attacked (as shown in Figure 1) and failed. Replacements are being made of round pipe which can be washed clean.

Conclusions

From this salt corrosion attack, several factors for future design of scrubbers have been learned:

1. Crevices and square corners should be eliminated if possible so that salt cannot collect in areas not flushed by water showers.
2. On lap welds, welding should be made from the inside to avoid crevices for salt accumulations.
3. Braces should be round; flat areas on the under side should be avoided.
4. Sufficient showers should be installed to wet the walls in areas of stagnant gas flow.
5. Where the gas changes from dry to wet conditions, the change should be made where the opening into the scrubber is the smallest. This area will require more repair or more expensive materials to control the corrosion.

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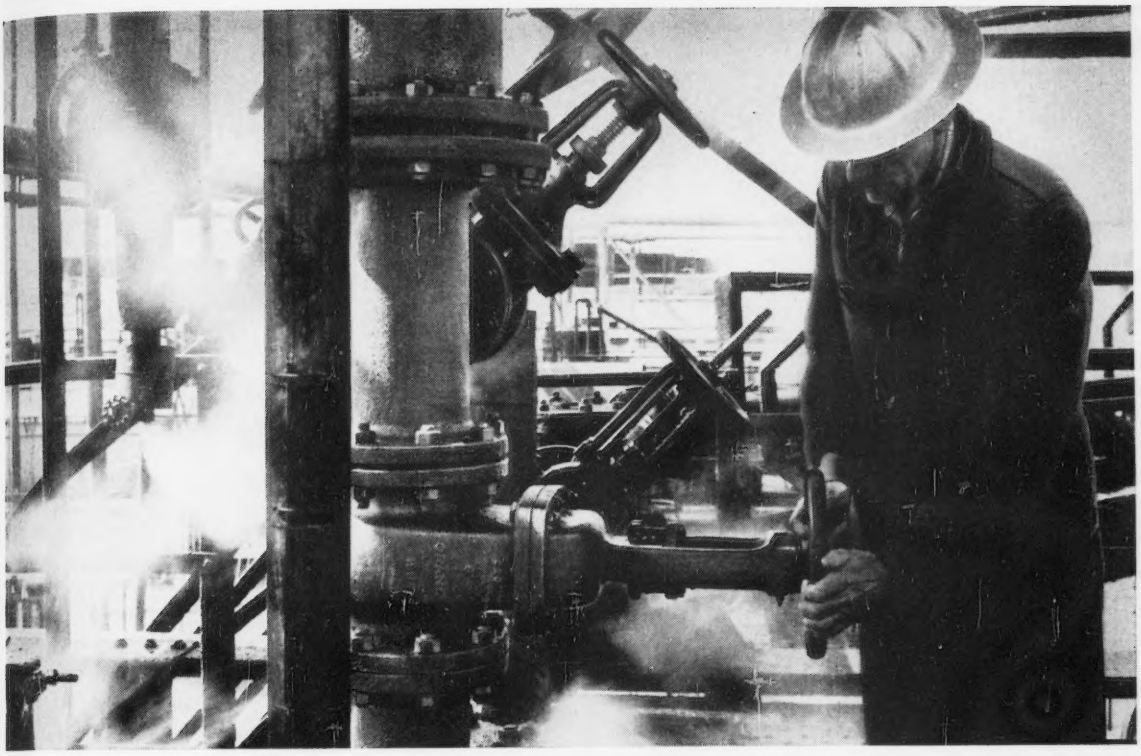

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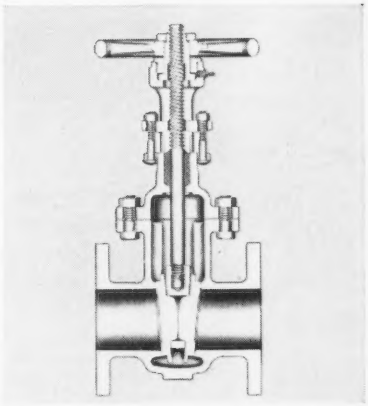

Crane Combines Corrosion-Resisting Alloy, Wear-Avoiding Design. High nickel and chromium contents of the alloy, combined with copper and molybdenum, afford outstanding resistance to sulfuric acid and other corrosives. Split-wedge disc closure enables parts to seat with lighter-than-average pressure... minimizes critical wear and galling. *Crane Co. trademark

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How Cathodic Protection Affects Shipbottom Coatings*

W. J. Francis
Norfolk Naval Shipyard
Norfolk, Virginia

Herman S. Preiser and Frank E. Cook
Bureau of Ships, Washington, D. C.

TESTS REPORTED here are continuations of preliminary investigations made in 1951 by the Bureau of Ships in cooperation with International Nickel Co., Inc., and Dow Chemical Company on the effect of controlled electrical potentials on underwater paint systems.

The problem of finding suitable paints and coatings for use in combination with cathodic protection can be divided into two parts.

a. For over-all protection of the hull, the paint system should be capable of withstanding cathodic potentials of about 1.0 volt.* Normally —0.78 volt is considered the optimum protective potential for most conditions.

b. Coatings on hull areas, in the vicinity of many energized anodes and certain galvanic anodes, should be capable of withstanding cathodic potentials above 1.0 volt.

Objectives of Tests

As a consequence of this dual-sided problem, two studies were undertaken with the following objectives:

1. To find suitable paints and coatings resistant to cathodic potentials of 1.0 volt with the emphasis on complete hull systems having the requisite antifouling character.

2. To find heavy duty paints and coatings resistant to potential gradients to six volts for use as dielectric shields or blankets near energized inert anodes. These shields usually cover an area of the hull extending five feet radially from the anode edge. No emphasis was placed on the antifouling character of the coating but in all cases the adhesion of conventional Navy vinyl antifouling topcoats was observed.

An ideal coating for use as a dielectric shield should be a non-conductor with easy application, high degree of adhesion, resistance to alkali (cathodic reaction products), impermeability to seawater, toughness, flexibility and ability to withstand continuously impressed cathodic voltages to 6.0 volts.

This series of tests was made on sandblasted mild steel panels, coated with a system consisting of an undercoat (anti-corrosive system) and the topcoat (antifouling system). Coatings and sources are listed in Table 1.

After coating, the panels were submerged in seawater at International Nickel's Harbor Island Test Station of International Nickel Co., Inc. Tests were made at cathodic potentials of 1.0 volt, using galvanic anodes and at 1.5 to 6 volts using energized steel anodes.

Results of the tests on hull paint systems at 1.0 volt are given in Figure 1. Figure 2 gives results of exposures on dielectric shield materials from 1.5 to 6 volts.

(Continued on Page 14)

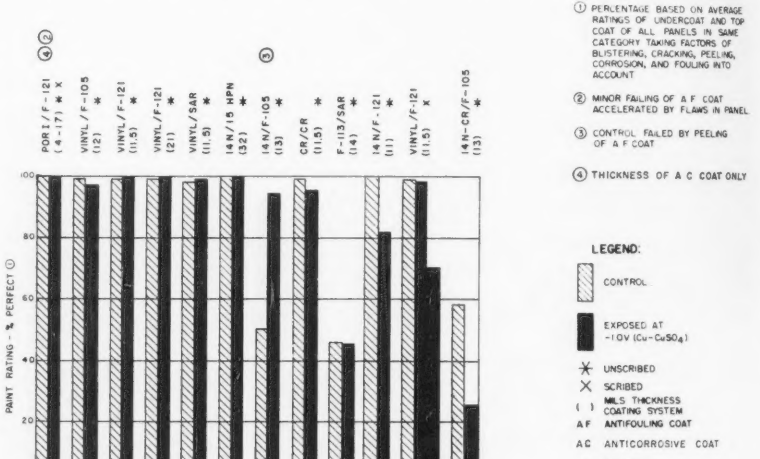
POR I/F-121 (4-17) * X
VINYL/F-105 (12) *
VINYL/F-121 (11.5) *
VINYL/F-121 (21) *
VINYL/SAR (11.5) *
14N/15 HPN (32) *
14N/F-105 (13) *
CR/CR (11.5) *
F-113/SAR (14) *
14N/F-121 (11) *
VINYL/F-121 (11.5) X
14N-CR/F-105 (13) *
PAINT RATING - % PERFECT ①
SEAWATER EXPOSURE - MONTHS
NOTES:
① PERCENTAGE BASED ON AVERAGE RATINGS OF UNDERCOAT AND TOP COAT OF ALL PANELS IN SAME CATEGORY TAKING FACTORS OF BLISTERING, CRACKING, PEELING, CORROSION, AND FOULING INTO ACCOUNT
② MINOR FAILING OF A F COAT ACCELERATED BY FLAWS IN PANEL
③ CONTROL FAILED BY PEELING OF A F COAT
④ THICKNESS OF A C COAT ONLY
LEGEND:
CONTROL
EXPOSED AT -1.0V (Cu-CuSO4)
* UNSCRIBED
X SCRIBED
( ) MILS THICKNESS COATING SYSTEM
AF ANTIFOULING COAT
AC ANTICORROSIVE COAT
-/- AC/AF
NOTE: SEE TABLE 2 FOR KEY TO COATING SYMBOLS

Figure 1—Coating performance versus exposure time for panels exposed to a cathodic potential of 1.0 volt.

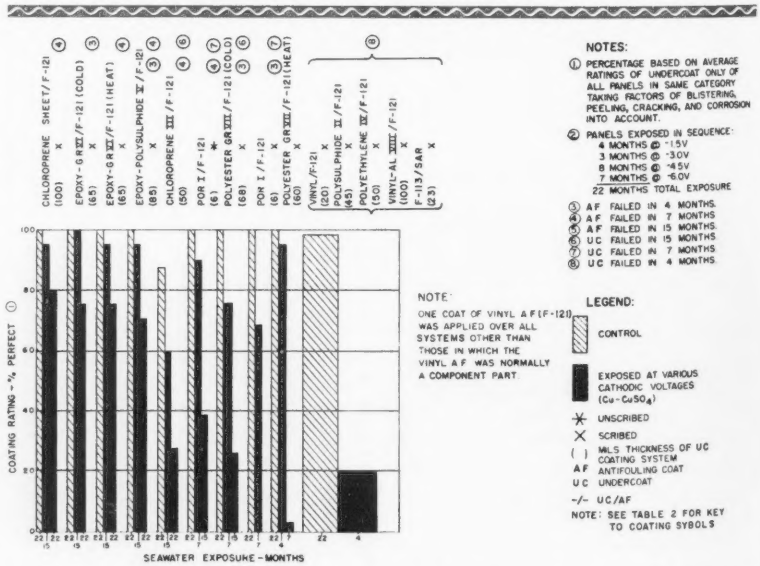
CHLOROPRENE SHEET/F-121 (100) X
EPOXY-G RII/F-121 (COLD) (65) X
EPOXY-G RII/F-121 (HEAT) (65) X
EPOXY-POLYSULPHIDE II/F-121 (85) X
CHLOROPRENE III/F-121 (50) X
POR I/F-121 (6) * X
POLYESTER GR VIII/F-121 (COLD) (68) X
POR I/F-121 (6) X
POLYESTER GR VIII/F-121 (HEAT) (68) X
VINYL/F-121 (100) X
POLYSULPHIDE II/F-121 (45) X
POLYETHYLENE IX/F-121 (50) X
VINYL-AL. XIII/F-121 (100) X
F-113/SAR (23) X
COATING RATING - % PERFECT ①
SEAWATER EXPOSURE - MONTHS
NOTE: ONE COAT OF VINYL A F (F-121) WAS APPLIED OVER ALL SYSTEMS OTHER THAN THOSE IN WHICH THE VINYL A F WAS NORMALLY A COMPONENT PART
NOTES:
① PERCENTAGE BASED ON AVERAGE RATINGS OF UNDERCOAT ONLY OF ALL PANELS IN SAME CATEGORY TAKING FACTORS OF BLISTERING, PEELING, CRACKING, AND CORROSION INTO ACCOUNT.
② PANELS EXPOSED IN SEQUENCE:
4 MONTHS @ -1.5V
3 MONTHS @ -3.0V
8 MONTHS @ -4.5V
7 MONTHS @ -6.0V
22 MONTHS TOTAL EXPOSURE
③ AF FAILED IN 4 MONTHS.
④ AF FAILED IN 7 MONTHS.
⑤ AF FAILED IN 15 MONTHS.
⑥ UC FAILED IN 15 MONTHS.
⑦ UC FAILED IN 7 MONTHS.
⑧ UC FAILED IN 4 MONTHS.
LEGEND:
CONTROL
EXPOSED AT VARIOUS CATHODIC VOLTAGES (Cu-CuSO4)
* UNSCRIBED
X SCRIBED
( ) MILS THICKNESS OF UC COATING SYSTEM
AF ANTIFOULING COAT
UC UNDERCOAT
-/- UC/AF
NOTE: SEE TABLE 2 FOR KEY TO COATING SYBOLS

Figure 2—Coating performance versus exposure time for panel exposed to cathodic potentials of 1.5 to 6.0 volts.

* All potentials refer to the closed circuit potential readings recorded at the panel surface by means of saturated calomel half-cell unless otherwise noted.

★ Summary and extracts from the article "Cathodic Protection—Its Effect on Shipbottom Coatings" *AM Soc Naval Eng J*, 401-421 (1958) August. Article was based on a presentation made at a meeting of the Western Region, National Association of Corrosion Engineers, San Diego, Cal., October 23-25, 1957.

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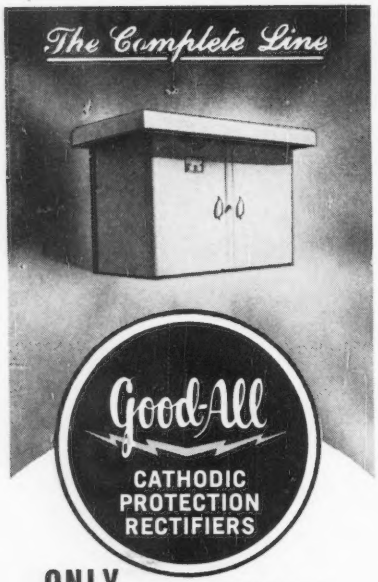

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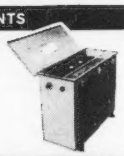

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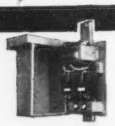

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Shipbottom Coatings—

(Continued From Page 12)

Of the control panels exposed without cathodic protection, 16 of the 23 systems showed little or no damage (rating about 95 percent), three systems showed moderate failure (rating 80 to 87 percent) and four systems had gross failure.

Based on the results of 22 months' exposure, the following conclusions can be drawn:

Five of the eleven coating systems tested under —1.0 volt exposure are compatible with cathodic protection: (a) Vinyl/F-121. Standard Navy Vinyl System in 20 and 10 mil thicknesses, (b) 14N/15HPN, Standard Navy Hot Plastic System, 32 mils thickness, (c) POR 1/F-121, Porcelain enamel coating, 4-17 mils thickness, (d) Vinyl/SAR, Standard Navy Vinyl anticorrosive with experimental Saran antifouling coating, 11.5 mils thickness and (e) Vinyl/F105, Standard Navy Vinyl anticorrosive with Cold Plastic antifouling coating, 12 mils thickness.

Of the 14 dielectric shield coatings tested cathodically under potentials of —1.5 to —6.0 volts for 22 months' exposure, three coating systems which can be readily applied are considered satisfactory for ship bottom service: (1) Chloroprene/F-121: sheet chloroprene 125 mils thickness; (2) Epoxy-Gr VI/F-121, epoxy-glass reinforced, cold cure laminate, 65 mils thickness and (3) Epoxy-Polysulphide V/F-121: Epoxy-Polysulphide Copolymer, troweled on, cold cure, 85 mils thickness.

FOCUS on CATHODIC PROTECTION

Seven technical papers on various cathodic protection subjects will be included in the "Focus on Cathodic Protection" to be published in the January issue. Topics include economics of pipeline cathodic protection, an unusual problem at a marine aquarium, cathodic protection and cleaning of heat exchangers and three papers in a symposium titled "Methods and Experiences in Underground Cathodic Protection."

TABLE 1—Description of Coating Material

Code*	Undercoat System	Panel Source**
I	Porcelain	1
	Navy F-117 pretreatment (MIL-C-15328)	
	Navy F-119 vinyl red lead primer (MIL-P-15929)	
	Navy F-120 vinyl zinc chromate primer (MIL-P-15930)	
	Navy F-14N anticorrosive paint (MIL-P-19453)	2
	Norfolk L-223-27 anticorrosive paint (F-14N with chlorinated rubber)	
	Navy F-113 vinylidene chloride acrylonitrile copolymer	
	Norfolk L-255-1A anticorrosive paint (chlorinated rubber type)	
II	Polysulfide rubber, flame spray	
III	Chloroprene, brush-on, hot air cure	
	Chloroprene sheet, cold bond (MIL-R-15058)	
IV	Polyethylene, flame spray	
V	Epoxy-polysulfide, cold cure	3
VI	Epoxy-glass, cold cure	
VI	Epoxy-glass, heat cure	
VII	Polyester-glass, cold cure	
VII	Polyester-glass, heat cure	
VIII	Vinyl, aluminum pigment	
IX	Rubber formulation	
X	Rubber formulation	
XI	Rubber formulation	
XII	Epoxy-glass	1
XIII	Porcelain	
XIV	Porcelain	
XV	Vinyl	
	Topcoat Systems (Antifouling)	
	Navy vinyl, red F-121 (MIL-P-15931)	
	Navy cold plastic F-105 (MIL-P-18943)	
	Norfolk L-223-202 (Saran base)	2
	Norfolk L-223-200-1 (Chlorinated rubber-rosin-Cumar)	
	Hot Plastic F-15 HPN (MIL-P-19452)	

*All proprietary coatings are coded by Roman Numerals.
**Panel sources as follows: 1 = Industry; 2 = Norfolk Naval Shipyard; 3 = New York Naval Shipyard.

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Humble coatings provide lasting protection against internal corrosion. This means longer pipe life, especially in sour crude and brine lines. Iron oxide is eliminated as a source of product contamination and as pipeline dust that damages valves, fittings and orifice meters.

For information on epoxy coatings, and on Humble's complete line of paints and protective coatings, call your Humble salesman or contact Humble Oil & Refining Company, Houston, Texas

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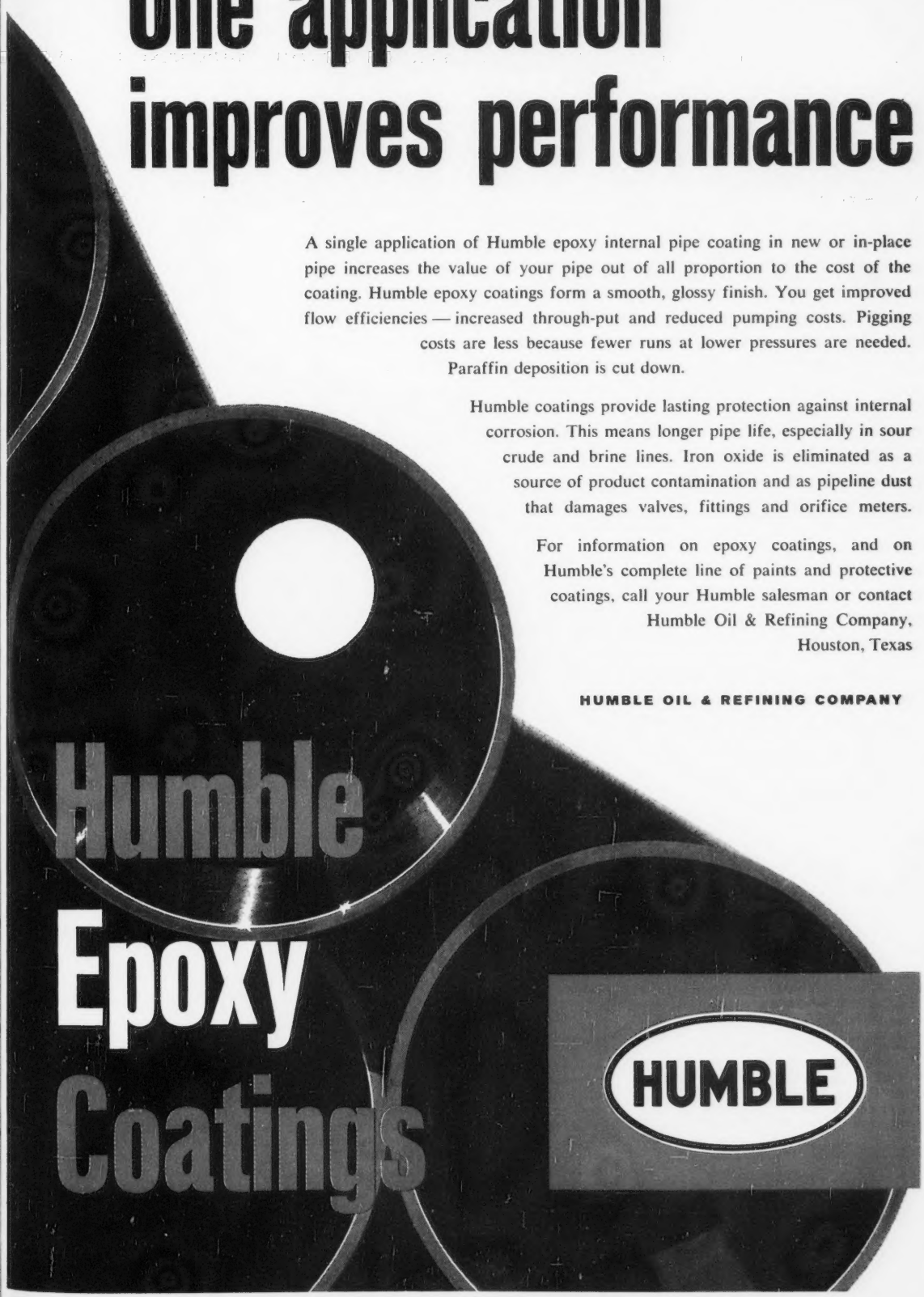

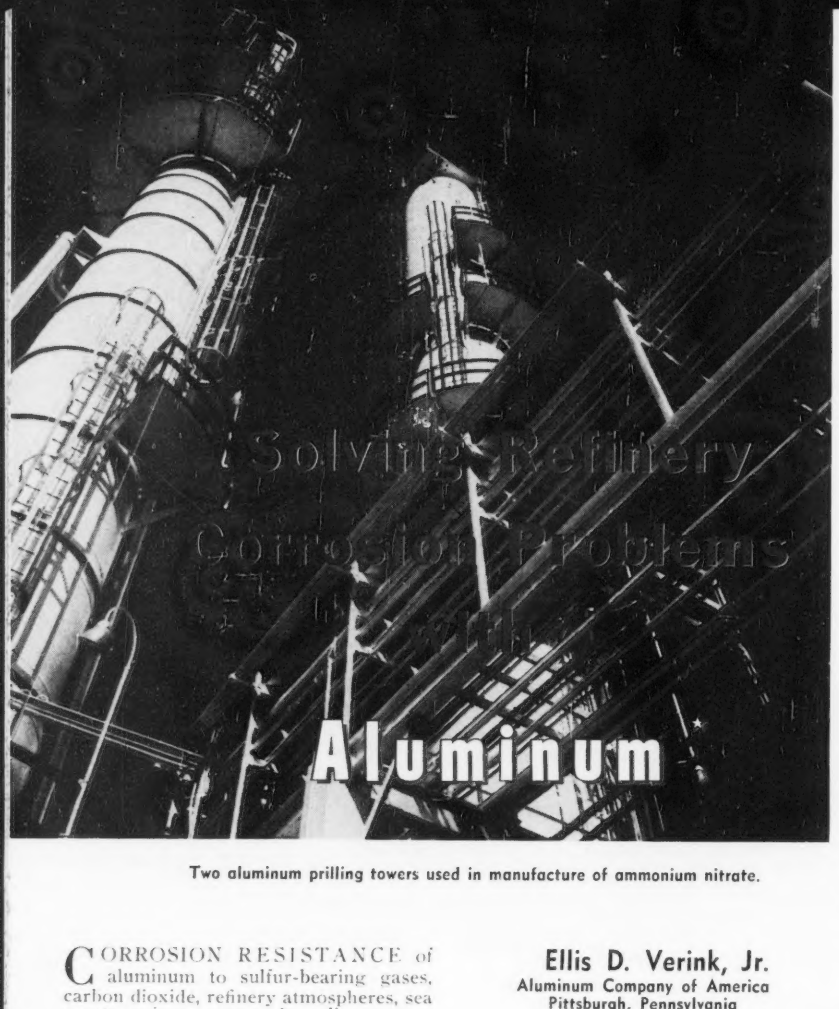

Two aluminum prilling towers used in manufacture of ammonium nitrate.

Solving Refinery Corrosion Problems with Aluminum

Ellis D. Verink, Jr.
Aluminum Company of America
Pittsburgh, Pennsylvania

Frank B. Murphy
Aluminum Company of America
New Kensington, Pennsylvania

Abstract

Describes various applications of aluminum in the refining industries to control corrosion. These include offshore and marine applications, heat exchangers, piping and tubing, tank and transportation uses, tower internals and cryogenic equipment. Bibliography with 24 items given. 6.4.2

CORROSION RESISTANCE of aluminum to sulfur-bearing gases, carbon dioxide, refinery atmospheres, sea coast environments and cooling waters plus general availability and an increasing cost advantage have accounted for the expanded use of aluminum alloys in the refining industry. Developments in the extrusion of aluminum tubing with specified wall thickness and thicker ends for welding and aluminum single and double traced pipe also have expanded the uses of this material for corrosion control in the petroleum and chemical industries.

This article gives examples of the corrosion control applications of aluminum relative to the refining industry.

Atmospheric Exposures

Because of its resistance to atmospheric exposure, aluminum is used for windows, stairways, railings, tread plate, spandrels, roofing, siding, weatherproofing for thermal insulation, nails, paint, etc. Colored aluminum jacketing provides a new method for enhancing plant appearance. When used to weatherproof thermal insulation on refinery piping and equipment, colored jacketing also can be used as color coding.

In coastal, industrial and refinery atmospheres, aluminum cable, conduit, connection boxes and lighting fixtures are used to solve the maintenance problem.

Offshore and Marine Applications

Aluminum is being used in offshore and marine applications to withstand the serious corrosion problems created by marine environments. Aluminum Architectural items such as gratings, walkways, roofing, siding, conduit and handrails are used on offshore drilling structures. Aluminum galvanic anodes protect submerged steel structures.

Aluminum piping has been used to solve the corrosion problem. For example, aluminum piping was used in Lake Maracaibo, Venezuela, because marine organisms destroyed protective coatings on steel pipe. Aluminum has ten times the corrosion resistance of unprotected steel in Lake Maracaibo water.

Heat Exchanger Applications

Combining low initial cost with resistance to hydrogen sulfide, ammonia, carbon dioxide, hydrocarbons and cooling waters, aluminum heat exchanger tubes have given good service as catalytic cracking overhead condensers and as compressor intercoolers and aftercoolers. In one refinery, aluminum tubes are used in a heat exchanger handling the separated water phase from catalytic cracking in which ammonia and hydrogen sulfide are present in considerable amounts. Aluminum tubing is used to replace copper-base alloy tubing which is susceptible to corrosion by ammonia.

Catalytic polymerization and coking of furfural are familiar problems when copper-base alloy tubes are used for furfural refining. Tests prove that aluminum is as inert as glass to refined products such as lubricating oils. Thus aluminum is being used for lube oil and furfural coolers.

Based on over eight years' service, one refinery has reported savings of $1000 per year in maintenance on each of several head exchanger bundles made of aluminum to handle furfural and furfural raffinates in a lube oil plant.

A typical refinery heat exchanger bundle of aluminum alloy is shown in Figure 1.

Aluminum heat exchanger tubes are used in production of gasoline from natural gas. Natural gas compressor intercoolers and aftercoolers have been tubed with aluminum and have been in continuous operation over nine years. Depropanizer and debutanizer overhead condensers with aluminum alloy tubes are proving successful.

Lean oil, rich oil heat exchangers having aluminum tube bundles are being substituted for steel because of lower initial cost and because of aluminum's resistance to hydrogen sulfide contamination. Operation temperature of these oil coolers is about 475 F. Several of these units have been operating satisfactorily at this temperature with aluminum tubes rolled directly into steel tube sheets. Generally, however, the use of aluminum tube sheets, rather than steel, would be recommended for temperatures above 250 F. This eliminates possible loosening of the tubes from differential thermal expansion when the temperature fluctuates widely.

Other Tubing Applications

The percentage of sulfur-laden (sour) crudes and products to be handled is increasing. Resistance to these corrosives, aluminum tubes have been used successfully in desulfurization of gaseous and liquid hydrocarbons. Aluminum has been used in gas coolers, solution coolers, lean-rich exchangers, towers and tower packing used in conjunction with amine strippers for resistance to corrosion by hydrogen sulfide and carbon dioxide.

The success of aluminum tubes in oil refineries, gasoline plants and chemical installations results primarily from the outstanding performance of alclad aluminum tubes with fresh, salt, and brackish cooling waters. No alclad tubing failures attributable to the cooling water (either fresh or salt water) have been observed, either in service installations or in experimental units. One installation has been in fresh water service for 17 years; another in salt water service for 10 years.

There is considerable interest in the use of aluminum heat exchangers, pipe and evaporation equipment for saline water conversion plants. Installations on the Texas Gulf and Atlantic coasts, where heavy industrial contamination exists, have indicated the good resistance of alclad aluminum heat exchanger tubes to these waters. Although alclad tubes are generally recommended in preference to nonclad tubes, especially when there is

★ Revision of a paper presented at the 16th Annual Conference, National Association of Corrosion Engineers, March 14-18, 1960, Dallas, Texas.

no service experience or complete analysis of the water, nonclad alloy tubes are being used with cooling waters determined not corrosive to the alloy. Nonclad tubes are used when cooling water is free of traces of compounds of metals such as copper, lead, tin, etc.

Aluminum alloy tube sheets generally are recommended for use with aluminum tubes. With cooling waters having a chloride content less than approximately 50 ppm, aluminum tubes have been used successfully with mild steel tube sheets. If inspection reveals galvanic corrosion, aluminum anodes or zinc bolted or sprayed on the water-side face of the tube sheet can reduce galvanic attack. In many instances, organic coatings can be used to protect steel tube sheets.

Tank and Transportation Uses

Aluminum storage tank roofs for sour crude oils have been in service over 20 years in locations where steel roofs failed in less than five years. In most environments, external painting is not required to protect aluminum tanks.

Aluminum's serviceability with refined products is well illustrated by the widespread installation of aluminum piping systems for delivery of aircraft fuel to loading stations at commercial and military air fields. Aluminum is employed to avoid corrosion and scale contamination. Aluminum portable piping systems serve oil producers as drilling rig supply pipe, tank battery piping and vent lines. The light weight and corrosion resistance of aluminum are advantageous. In chemical plants, the use of aluminum pipe and fittings is customary in connection with aluminum tankage and equipment.

Also, aluminum's nonsparking characteristic and the light weight are advantageous in material handling equipment. One large oil company uses aluminum drum skids, dock plates, etc. Aluminum fittings are used on oil unloading hose; aluminum loading arms with aluminum swivel joints are used to tranfer oil to tankers at docking facilities.

Use of aluminum for transportation equipment is growing in the expanding petrochemicals industry. A fleet of aluminum tank cars is in service transporting synthetic glycerine. Aluminum alloy tank cars also carry ammoniated ammonium nitrate solutions, acrylonitrile, acetic acid, formaldehyde, etc. Over 2000 cars carry ammonium nitrate solutions alone. Aluminum has given long and successful service with fatty acids, aldehydes and ketones. Aluminum not only resists corrosive action by these products but does not cause discoloration or breakdown of the product handled.

Tower Internals of Aluminum

Aluminum bubble caps have given service from 10 to 15 years in debutanizer columns handling gasoline distillate from West Texas sour crudes at temperatures from 200 to 425 F. Similar service has been realized from aluminum bubble caps in cracking unit fractionating columns for sour crude gas oils at temperatures from 400 to 625 F. One major refiner uses aluminum bubble caps throughout one of its refineries for both sweet and sour stocks except where caustic or strong mineral acids are encountered. Although cast and wrought aluminum alloys have been used for this service, the wrought alloy caps may have several advantages over the cast caps because they should have less tendency to "coke-up" and are

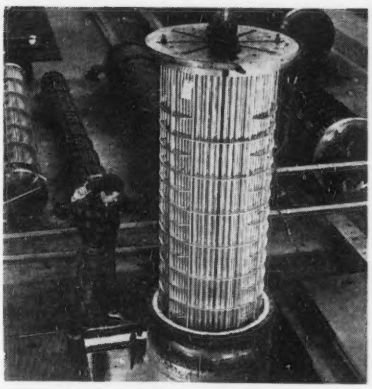

Figure 1—Typical refinery heat exchanger bundle of aluminum alloys.

lighter and more ductile. Aluminum Raschig rings are used in carbon dioxide and hydrogen sulfide scrubbing and absorption towers; expanded aluminum mesh has been used in a number of services.

Cryogenic Equipment

Large tonnage oxygen plants designed for use with Fischer-Tropsch synthesis plants have been built almost entirely of aluminum. Similar plants are in the construction stage. Selection of aluminum was based on its low cost compared to competitive materials, desirable physical properties, corrosion resistance and ease of fabrication. Having no embrittlement at low temperatures, aluminum alloys have been selected for fabrication of pressure vessels, pipe, tankage, complex heat exchangers and transportation equipment designed to handle liquefied gases such as methane, ethylene, oxygen, nitrogen, hydrogen, and helium. Aluminum forms no explosive acetylides.

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(Continued on Page 20)

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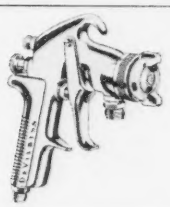

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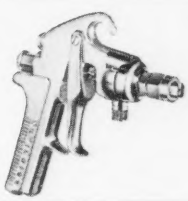

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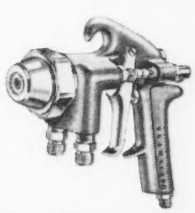

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Take, for example, the needs of a low pressure polyethylene process such as the one diagrammed below. The primary need here is for equipment which will not impart contaminants which discolor the product. The obvious design answer is aluminum with its demonstrated ability to prevent such contamination. Add to this such other important aluminum design benefits as these:

It provides a level of corrosion resistance unique among commonly used metals; its low temperature properties are outstanding (tensile and yield strengths actually increase without embrittlement as operating temperatures drop); it is nontoxic; its strength-weight ratio surpasses that of nearly every other metal; and its first cost is far lower than that of other suitable materials.

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And polyethylene represents just one of literally hundreds of processes in which aluminum provides important design benefits on equipment applications of nearly every type. A few of these are shown on the opposite page. In nearly every case, aluminum's benefits can be predicted with surprising accuracy—thanks to the large volume of factual service data developed by Alcoa in well over 40 years of applying aluminum to process equipment requirements. Alcoa engineers are anxious to share this experience with you. They are doing so through a series of engineering conferences being held this year in major cities throughout the country. Your local Alcoa sales office will furnish you with details.

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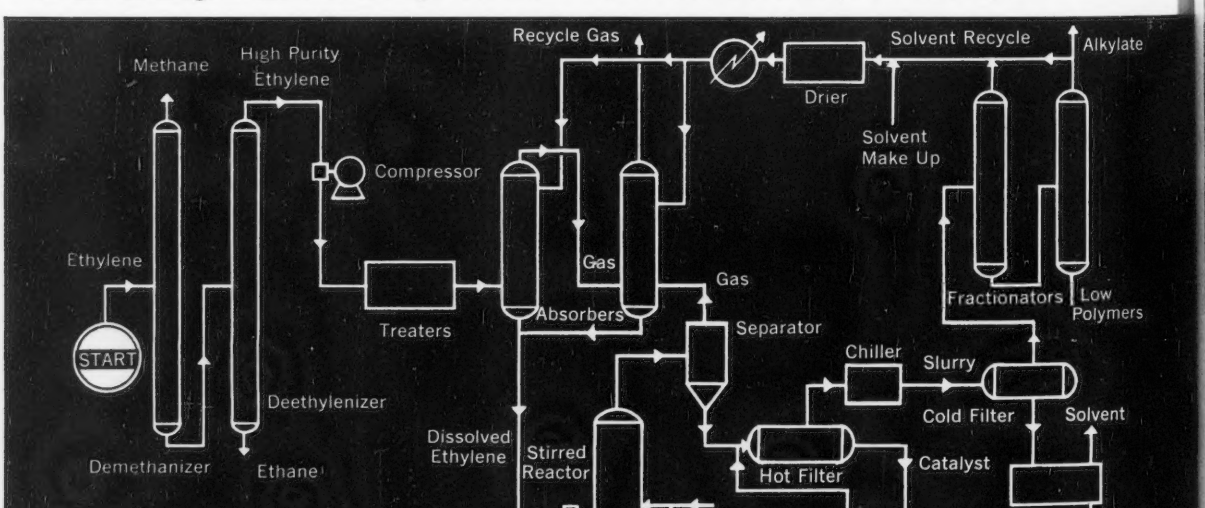
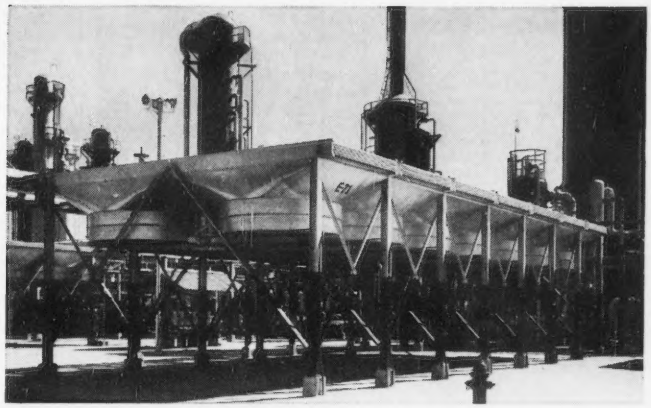
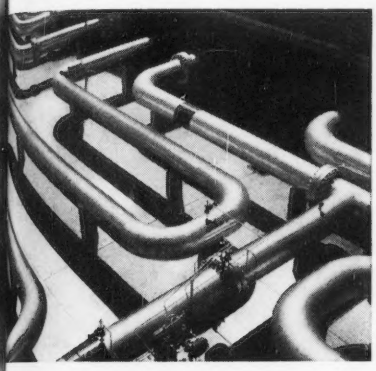


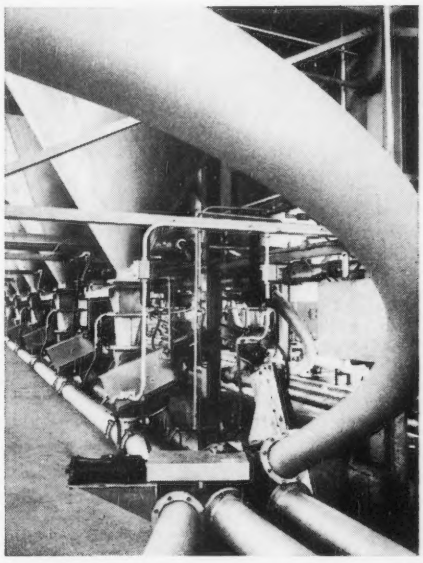
Detailed here is a typical low pressure polyethylene process. The various applications in which aluminum has proved its superiority in actual use are indicated . . . as are those additional applications for which the unusual properties of aluminum appear to make it highly suitable.



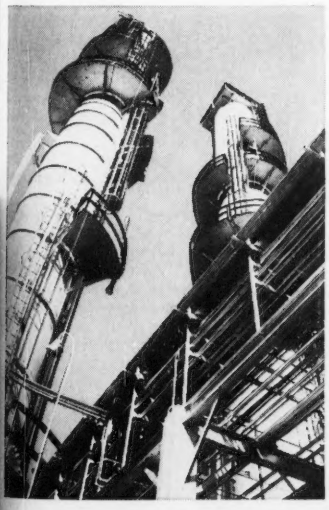
Below, aluminum's ability to maintain its serviceability and excellent appearance in chemically contaminated atmospheres is utilized here in Al-Cor-Jac alclad aluminum jacketing—manufactured by Insul-Coustic Corporation, Maspeth, Long Island, N.Y.



Pictured above is a Solo-aire cooling unit manufactured by Hudson Engineering Corporation, Houston, Texas. Here the excellent heat transfer properties of aluminum made it a natural choice for process cooling. Of important added value are the excellent corrosion resistance of aluminum and its outstanding low temperature properties.



Right, this polyethylene process employs a variety of aluminum applications to prevent product discoloration. Since the process operates at extremely low temperatures, aluminum's excellent low temperature durability is an important asset in piping, bins, hoppers and vessels.



These prilling towers and nearly all of the piping and equipment surrounding them are aluminum. Selection of Alcoa Aluminum was based upon the metal's unique ability to withstand corrosive attack in this nitrogen fertilizer operation — plus its excellent strength-weight ratio which contributes to economical design by eliminating the need for excessive structural support.

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- ☐ 10418 Alcoa Unitrace: Combines Piping and Tracing in One Unit
- ☐ 514 Alcoa Duotrace Technical Report
- ☐ 10270 Alcoa Utilitube
- ☐ 10460 Process Industries Applications of Alcoa Aluminum
- ☐ 11453 Solving Refinery Corrosion Problems with Aluminum
- ☐ 20849 Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres
- ☐ 20437 Aluminum Alloy Heat Exchangers in the Process Industries
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Refinery Corrosion—

(Continued From Page 17)

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DISCUSSIONS

Question by Walter C. Harbison, El Dorado, Arkansas:
What is a tolerable level of chlorides in circulating cooling water systems when using aluminum tubes and bundles?

Reply by R. L. Horst, Aluminum Company of America, New Kensington, Pennsylvania:
Alclad aluminum tubes are preferred for handling saline waters and have demonstrated service lives of 10 years in most fresh waters where the chloride content is low. Galvanic action between aluminum and carbon steel has not proven to be significant in waters with a chloride content below 50 ppm.

Questions by Andrew Dravnieks, Standard Oil of Indiana, Whiting, Indiana:
What is the state of art in predicting whether aluminum alloy cooler tubes would perform well in certain refinery units on the water side? Is it possible from water analysis and other pertinent data such as plant layout (other coolers) to say with certainty that aluminum tubes will or will not work?

Reply by Frank B. Murphy:
Several methods of evaluation may be used in an attempt to predict the service life of aluminum tubes in refinery heat exchanger service. A cooling water analysis will give important data such as pH, chloride content, heavy metal contamination and relative hardness. The neutral range for aluminum tubes in water service is considered to be between a pH of 4.5 and 8.5 even if these cooling waters contain salts of the alkali metals or alkaline earth metals. The action of waters having a pH greater than 8.5 depends on the compounds which cause the relatively high alkalinity. In the case of acid water where the pH values are less than 4.5, the rate of attack is governed by water composition and acidity. Presence of chlorides is known to promote corrosion in acid waters.

Even traces of heavy metals such as copper, lead, cobalt, nickel, silver or tin may cause corrosion of aluminum alloys. Location of heavy metal equipment and piping on the upstream water side of aluminum exchangers will, of course, contribute greatly to the heavy metals content of the water. Alclad aluminum products are designed to give long life in fresh or salt cooling waters even in the presence of heavy metal compounds.

Mercury compounds can be seriously corrosive to many non-ferrous metals, including aluminum alloys. Special water analysis techniques can detect the presence of mercury in cooling waters.

Questions by Robert W. Manuel, New York City, New York:
Sometimes aluminum is used to replace steel in Admiralty bimetal tubes in amine regenerator overhead condensers (acid gas coolers) because of corrosion of the steel or because of the collapse of the Admiralty inner tubes due to hydrogen diffusion through steel. Would you use aluminum Admiralty bimetal tubes and what precautions would you take against galvanic corrision? If solid aluminum tubes are used, is there a method of removing heavy metals from the water ahead of the aluminum tubes? This would especially be of concern when other cooling equipment is mostly copper alloy.

Reply by Frank B. Murphy:
Aluminum-Admiralty bimetal tubes should perform satisfactorily in regenerator overhead condensers in non-eletrolytes which are used for cooling. In most cases, bimetallic tubes of this type would not offer any advantages over solid aluminum tubes and would be considerably more expensive. Aluminum tubes give excellent service in many regenerator overhead condensers and alclad tubes should be specified where water cooling is used.

Where heavy metals are known to be present in cooling waters, alclad aluminum tubes will afford protection against heavy metal attack. Where excessive heavy metals are contaminating the cooling water as a result of dissimilar equipment upstream, heavy metal scavengers or traps may be used. Such traps can be in the form of a filter unit containing aluminum shavings, machinings or wire through which the cooling water passes before it is introduced to the aluminum tube bundle. Aluminum alclad pipe ahead of the exchanger also has been used as a waster section to scavenge heavy metal ions.

Question by Alistair S. Couper, Whiting, Indiana:
What is the structural temperature limitation for aluminum alloy 5454?

Reply by Frank B. Murphy:
Alloy 5052 (2.5 per cent magnesium and 0.25 per cent chromium) has been used for many years and shows no susceptibility to stress corrosion under any conditions of cold work, stress, time, temperature or corrosive environment Alloy 5454 containing 0.8 manganese, 2.75 magnesium and 0.10 chromium, has been developed recently to meet the need for a maximum strength alloy which can be used in service at temperatures above 150 F. In accelerated tests, it has demonstrated freedom from susceptibility to stress corrosion cracking in cold worked as well as annealed tempers after heating for six months at the critical temperature of 212 F. Alloy 5454 therefore can be specified for structural applications where temperatures exceed 150 F for extended periods.

Question by James W. Edminister, Pampa, Texas:
Aluminum and its alloys show most corrosion resistance in neutral pH ranges. Is it a contradiction that aluminum performs well in low pH aqueous H_2S solutions?

Reply by Frank B. Murphy:
The neutral range for aluminum alloys in water service is considered to be a pH value of 4.5 to 8.5. It is true that aluminum alloys show highest resistance to corrosion within these pH ranges; however, in alkaline and acid water solutions on either end of this range, corrosion is determined not by pH alone but by the chemicals causing the acidity or alkalinity. For instance, if a high pH water is caused by sodium hydroxide, severe attack to aluminum equipment will occur. If the same pH level is brought about by additions of amines or ammonia, aluminum suffers little or not attack. On the acid end, aluminum is severely attacked by hydrochloric or sulfuric acid solutions but suffers little or no attack from organic acids such as CO_2 or H_2S.

Question by Fred W. Fink, Battelle Institute, Columbus, Ohio:
In regard to the pipe line installed in Lake Maracaibo, what were the reasons that cladding or some sort of sacrificial anode protection was not used?

Reply by E. T. Wanderer, Aluminum Company of America, New Kensington, Pennsylvania:
No cladding or cathodic protection was incorporated on the aluminum pipe lines installed in Lake Maracaibo simply because preliminary test work indicated such measures were unnecessary. Lake Maracaibo water has very little corrosive effect on aluminum alloys normally used for pipe lines. If action occurs, it is generally uniform at a rate of a few mils per year and is not mitigated by cathodic protection. However, if pitting were stimulated by contacts with dissimilar metals, for example, it would be expected that sacrificial claddings or galvanic anodes would provide acceptable corrosion control.

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CHEMICAL INDUSTRY FOCUS

Technical Topics to be published in the March issue will be focused on corrosion control problems in the chemical industry. Topics will cover problems in various pieces of process equipment and proper use of design and materials to control corrosion.

FREE SAMPLE

NEW ALL-WEATHER "SCOTCHRAP" BRAND PIPE PROTECTION TAPE NO. 40

Now—an all-season tape that handles the toughest jobs. Ideal for field-wrapping under cold weather and other adverse climatic conditions. Provides excellent insulation properties and improved electric strength; resists acids, alkalies, salts, oils, gasoline and naphtha. Try it yourself and see . . . send in the coupon below for your free 9-foot sample roll.

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Send me my free sample roll of your new all-weather "SCOTCHRAP" BRAND Pipe Protection Tape No. 40.

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any combination of coatings

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Information about SOMASTIC®, the world's most thoroughly tested pipe coating, is a "must" for every engineering file. For free reprints of scientific papers, plus a newly revised booklet on SOMASTIC® uses and specifications, return the coupon below. Information about HEVICOTE® concrete coating, including weight and displacement tables, is also available.

If you are planning a pipe-type high-voltage electric transmission system, or a pipeline, for gas, crude, or products, phone the H. C. Price Co. Pipe Coating Plant nearest you for consultation without obligation with an experienced Sales Engineer. Frequently, these consultations can be helpful in coating selection, pipe transportation, and over-all line economics.

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Eight Government Reports Available From Houston Office

Eight reports of probable interest to corrosion engineers are available from the Houston field office of the U. S. Department of Commerce, 610 Scanlan Bldg., 405 Main St., Houston 2, Texas. Prices and number of the reports are given below.

Mechanical Properties of Selected Alloys at Elevated Temperatures (PB 161 761) $4; Effect of Prior Creep on Mechanical Properties of a High Strength Heat Treatable Titanium Alloy, Ti-16V-25Al (PB 161 490) $2; Theoretical and Experimental Research in Thermoelectricity (PB 161 468) $3; Effect of Boron containing High Energy Fuel Combustion Products on Properties of Statically Stressed High Temperature Alloys (PB 161 658) $1.75; Physical and Mechanical Properties of Columbium and Columbium-Base Alloys (PB 151 082) $1.75; Delayed Failure and Hydrogen Embrittlement in Titanium (PB 151 139) $1.75; Development of Partially Volatile Brazing Filler Alloys for High Temperature Application and Resistance to Oxidation (PB 161 746) $1.25; Thermoelectricity Abstracts in three series (PB 161 301) $2.50; (PB 151 810) $2.25; (PB 151 657) $2.50.

Conference to Include Plant Maintenance Problems

Problem sessions on 11 types of plants will be included in the January 23-26 Plant Maintenance and Engineering Conference to be held in Chicago at the International Amphitheatre and the Palmer House.

The types of plants on which separate sessions will be given include automobile, chemical processing, electronic equipment manufacturing, textiles, cement, metal working and fabricating, paper, petroleum processing, food processing, research and development and steel.

Subjects to be discussed during conference sessions include welding in maintenance, accounting for maintenance costs, new materials and products for maintenance and keeping contamination out of air and water.

Sahara Pipelines

A second major pipeline is nearing completion across the Sahara Desert to transport crude oil from Edjele-Zaraitine-Tiguentourine fields to La Skira at the rate of seven million metric tons per year. A 24-inch, 412-mile steel pipeline has just been finished to pump oil from Hassi-Messaoud to the Mediterranean port of Bougie in eastern Algeria. A third line is planned for completion next year. This 24-inch, 530-mile pipeline will carry natural gas to the cities of Algiers and Oran to help encourage location of large scale industrial plants there.

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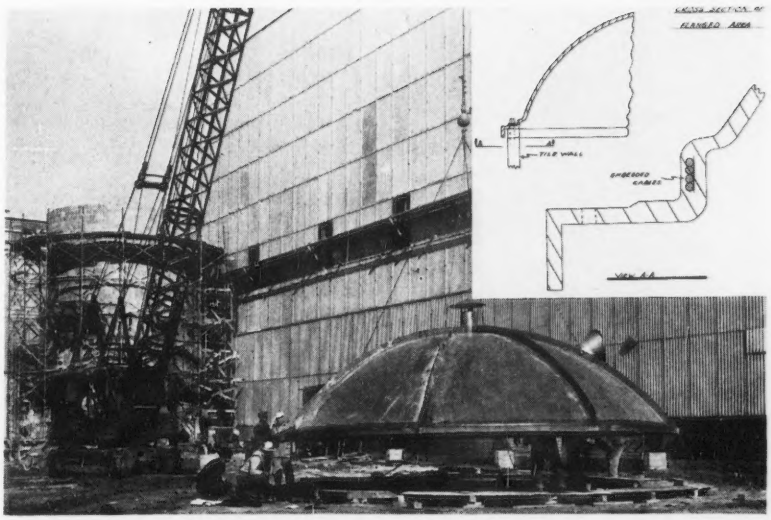
The 6th Annual Appalachian Underground Corrosion Short Course will be held June 6-8 at the University of West Virginia, Morgantown.

RECORD and REPORT



REINFORCED POLYESTER resin was used to fabricate this domed cover for a broke chest at an Alabama pulp and paper mill to combat corrosion. Stainless steel cables were wrapped around the cover base (as shown in the insert drawing above) to hold the polyester laminate in compression for full advantage of the strength of the fiberglas reinforced polyester resin. Bottom edge of the cover was turned down for a rain cap.

Corrosion Resistant Dome Roof Made of Reinforced Polyester

Fiberglass reinforced polyester resins were used to fabricate a 25-foot diameter broke chest cover to combat corrosion in an Alabama pulp and paper mill. Short service life and poor corrosion resistance were experienced with covers made of other construction materials.

To handle loads exerted on the cover, stainless steel cable was wrapped around the cover's base to hold the polyester laminate in compression, thus taking full advantage of the laminate's physical properties.

The cover's translucent quality permits clean-out inspection of the chest without additional lighting facilities. The resins can be pigmented to reflect sunlight and heat or to conform with plant color schemes if necessary.

The cover was fabricated and shipped in 8 pie-shaped pieces, then fastened together on the job by a cold bond process as shown in the accompanying photograph.

The domed cover was fabricated from Hetron, a polyester resin produced by the Durez Plastics Division of Hooker Chemical Corp., North Tonawanda, N.Y. Design and fabrication were by Metal-Cladding, Inc., North Tonawanda, N.Y.

Nace Technical Reports

STRESS CORROSION CRACKING. 15 papers reprinted from Corrosion. Pub. 59-4. Postpaid. Per copy $5

HIGH PURITY WATER CORROSION. Sixteen papers reprinted from Corrosion. Pub. 59-3. Postpaid, per copy.....$3

1957-58 NACE TECHNICAL REPORTS. 38 reports reprinted from Corrosion. Includes some in Pub. 59-2 and 3 above. Postpaid, per copy..$6.50

Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

Welding Society to Hold April 10-21 Convention

The American Welding Society will hold its 52nd annual convention and Welding Exposition in New York City, April 10-21. The society also will be host to the International Institute of Welding April 10-15 at the Sheraton-Atlantic Hotel. The AWS convention will be held at the Commodore Hotel; the Welding Show at the New York Coliseum. Additional information can be obtained from the society's information center, 33 West 39th St., New York 18, N.Y.

Which valve alloy?

Corrosion testing, which often includes analysis of test specimens like those shown above, insure Aloyco valve customers of the right alloy for each job. Typical metals used in Aloyco Valves: Types 304 and 316 Stainless Steel, Aloyco 20, Nickel, Monel, Hastelloy B, C and D.

At Aloyco, 30 years experience in stainless steel valves exclusively is at your service. Our field consulting service is yours for the asking.

On your next valve job call in the specialists . . . write Alloy Steel Products Company, 1304 West Elizabeth Avenue, Linden, New Jersey. 9.14

Longer Lasting ALOYCO VALVES

FIRST IN CORROSIVE SERVICE

ALLOY STEEL PRODUCTS COMPANY
Linden, New Jersey

Stainless Steel Valve Survives 31-Year Sulfur Dioxide Exposure

An 8-inch Type 316 stainless steel Y valve has given 31 years' satisfactory service in continuous exposure to hot sulfur dioxide gas in the sulfite pulp cooking system of a Maine mill. Installed in 1929 at the South Brewer, Maine mill of the Eastern Fine Paper and Pulp Division of Standard Packing Corp., the valve is located in the relief line between the digesters and the hot acid accumulator, as shown in accompanying photograph.

The valve was exposed to an operating temperature of 270 F and operating pressures from 45 to 50 psig. Pressure drop between the digesters and accumulator is about 12 psi.

Tests on Type 304 and 316 alloy specimens showed both to have corrosion rates of about 0.0001 ipy. But Type 306 was subject to attack under surface scale. Type 316 is resistant to localized attack under surface deposits.

Engineers at Alloy Steel Products Co., Linden, N.J., manufacturers of the valve, emphasized that these tests show that corrosive environments should be carefully studied in any given processing line before any specific valve or alloy can be safely recommended.

STAINLESS VALVE resisted corrosion attack for 31 years in continuous service exposure to hot sulfur dioxide gas in a pulp and paper mill. Valve was made of Type 316 stainless steel.

PERIODICALS

Combating Corrosion on Ship Hulls Through Cathodic Protection, Influence on Paint Systems. Publication 75 June, 1960. 11 pages. (In Dutch) By J. W. Doon, Metals Research Institute of The Netherlands, Postbox 52, Delft, The Netherlands. Per Copy, Francs 2.50.

Examination of the Properties of a Number of Rust Preventing Paints for Ship Hulls. Chapter I—Raft Specimens; Chapter II—Trial Specimens on Ships. (In Dutch). Publication 74. June, 1960. 15 pages. By H. W. Talen, W. J. Pfieffer and A. M. van Londen. The Metals Research Institute of The Netherlands, Postbox 52, Delft, The Netherlands. Price not indicated.

L'Acciaio Inossidabile. Bi-Monthly. Italian. 28 pages, 7¼ x 10 inches. March-April, 1960. 27th year. Published by Centro Studi Liai Lerici, Via Lancetti 36, Milan Italy. Per year, 2500 lira.

A periodical devoted to information about stainless steel. Contains technical articles and a bibliographic section. No advertising is included.

Current Contents, Eugene Garfield. Editor. Weekly. Nov. 1, 1960 issue 90 pages 5¼ x 8¼ inches. Institute for Scientific Information, 1122 Spring Garden St., Philadelphia 23, Pa. subscriptions—Industrial, $100; Non-profit, $50.

Consists of the photolithographed contents pages of 550 foreign and domestic periodicals. Annually this results in publication of over 125,000 titles including those reporting over 95 percent of all newly reported chemicals and drugs.

As indicated in the description included in the issue reviewed, emphasis is on chemistry.

Society to Sponsor Fourth Steel Development Contest

The Fourth Product Development Contest sponsored by the Product and Market Development Committee of Steel Founders' Society of America includes total cash awards of $10,000. Entries can be made in five fields, including metallurgical design involving consideration of physical properties of steel castings such as grain size and structure, temperature effects, corrosion resistance, wear resistance and electrical and elastic properties.

Additional information can be obtained from the society at 606 Terminal Tower, Cleveland 13, Ohio.

Packer Fluid Bulletin

A development bulletin on a packer fluid for completing wells and filling the annulus between casing and tubing is available from Dowell Division of Dow Chemical Co., P. O. Box 536, Tulsa, Okla. Called Heviwater, the fluid is a solution of fresh water, calcium chloride, suitable corrosion inhibitors and zinc chloride for use when fluid weight is to be above 11.8 pounds per gallon.

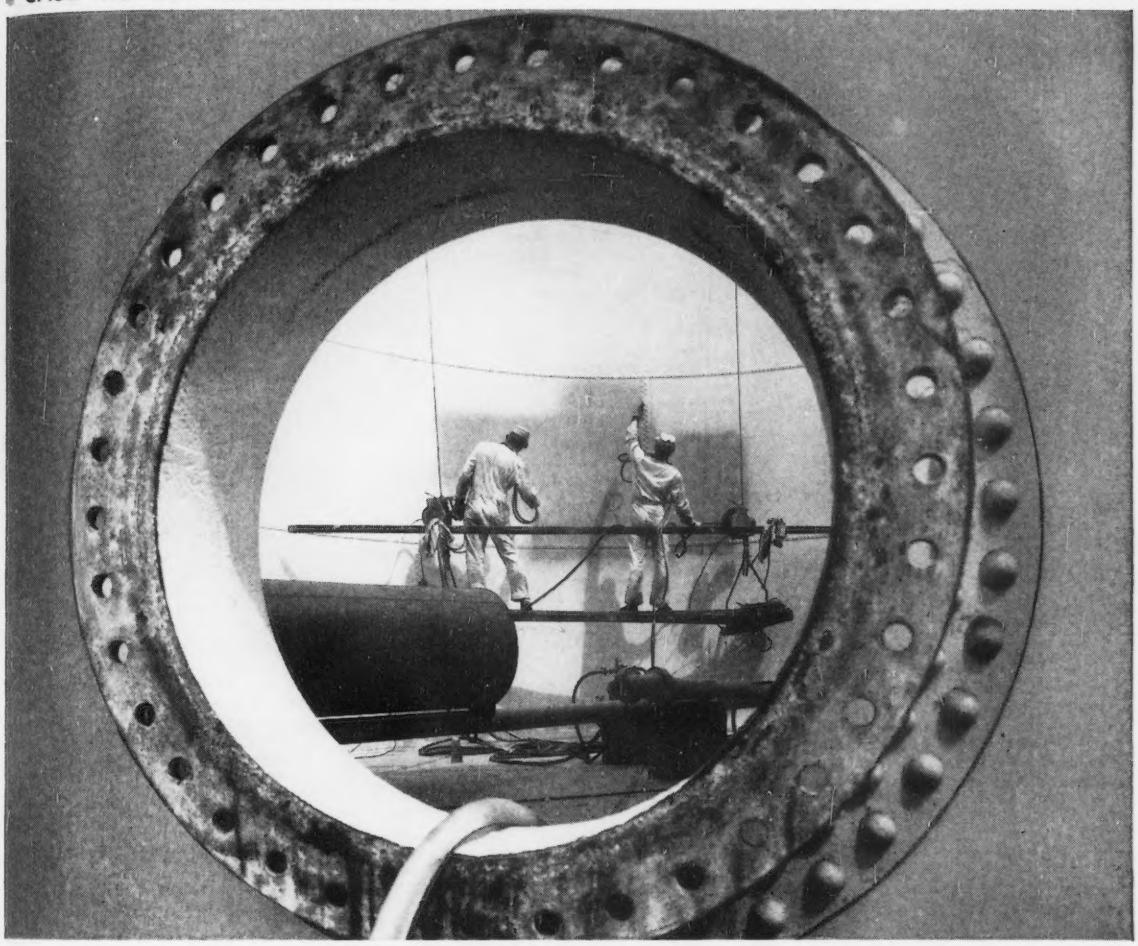
Russian Book in English

A book entitled "The Structure of Glass" was published simultaneously in New York City and Leningrad through the co-operation of American and Russian editors. English translations were made of the Russian galley proofs sent via airmail.

ASA Conference in 1961

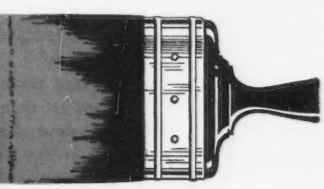
The American Standards Association will hold its 12th National Conference on Standards at the Rice Hotel, Houston, Texas, October 10-12, 1961.

CASE HISTORY REPORT NO. C-4



Interior of storage tank being coated by applicators of National Marine Coatings, Inc., San Pedro, California

Urethane coating resists solvent action . . . prevents rust contamination of aviation fuels



The urethane coating on the interior of Richfield Oil Corporation's storage tank for jet fuel is expected to last five years—at least 25% longer than the uncoated tank itself would last in direct contact with aviation fuels.

A serious problem in the oil and gas industries is tank metal loss through solvent action of stored petroleum products, leading to rust contamination of the fuel. After 2½ years of intensive research on this problem, Richfield concluded that the urethane coating (Laminar X500*) provides full bondage against vapor permeation of corrosive fuels which attacks other coatings within 30 days to one year after application.

Tests show that this highest-quality urethane coating, formulated with Mobay's Mondur CB resin, resists corrosion and abrasion better than six others tested—all epoxy, vinyl and silicon-zinc types. Labor savings up to 10% result from urethane's drying time of one hour at 70°F and 50% humidity. Flash point during application is 100°F., a full 15° higher than other standard coatings tested.

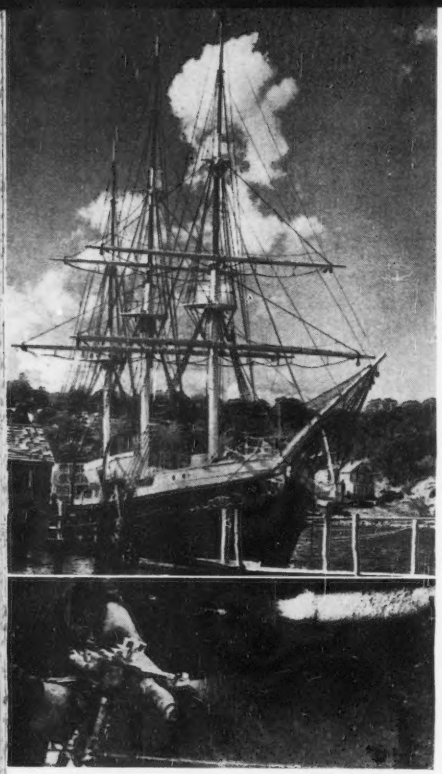
For further information on urethane coatings for maximum performance under extreme conditions, write Mobay Chemical Co., Code C-4, Pittsburgh 5, Pa.

*T.M. Magna Coatings & Chemical Corp.

Mobay is the only domestic supplier of all the basic chemicals required to formulate the various urethane coatings systems, and developed the original technology for urethanes in the U. S.

MOBAY

First in Urethane Chemistry



GLASS-RESIN COATING was sprayed on this 88-year-old iron hulled ship to prevent further corrosion damage. A special gun shown in the lower portion of the photograph mixes the glass-resin combination with an activator in proper proportions as the material is sprayed.

Glass-Resin Coating Protects Ship's 88-Year Old Hull

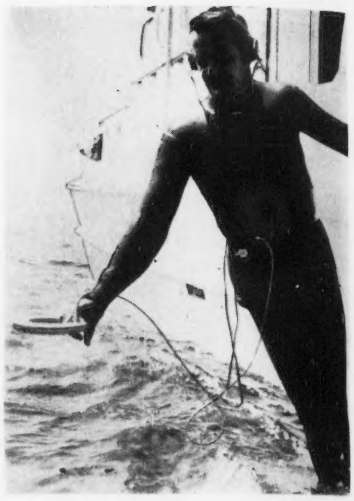
A newly developed protective coating composed of glass flakes and a polyester resin as bonding was applied to the deteriorating iron hull of the 88-year old "Joseph Conrad," a full rigged ship (shown in accompanying photograph) used in a youth training program by the Marine Historical Association, Inc., Mystic, Conn.

The 4600 square feet of hull surface have been sprayed with the new coating for protection against further corrosion damage. The iron plates had been badly corroded and pitted, particularly below the water line. In some areas the plates were so badly damaged that patch plates had to be welded into place.

Coating of the ship was begun after a successful test application of the flake coating on a 200 square foot patch of the ship's hull. This test showed the coating had good adhesion and permitted no water transmission to the iron hull after an 8-month exposure in tidewater.

The coating is applied by a special spray gun (shown in accompanying photograph) that draws simultaneously from a pot containing the glass flake mixed with the resin and a pot containing the activating agent. The gun mixes the glass-resin combination and the activator in proper proportions.

Called Fiberglas Flake, the coating was developed by Owens-Corning Fiberglas Corporation, National Bank Bldg., Toledo, Ohio. Gun and spraying equipment were developed by Glass Plastics Corporation, Linden, N.J.



PIPE DETECTOR used for finding underground pipe was used recently to locate two offshore pipelines. This detection job was unusual because the signal had to travel through 10 feet of mud and sand, 20 feet of water and 8 feet of air. The lines extended 4500 feet offshore for loading and discharging tankers. A signal was applied to the lines on shore with an audio oscillator. A boat made a series of oblique passes over the line with an operator suspending an 8-inch inductance coil held eight feet off the surface of the water, as shown in the above photograph.

Testing Standards Issued For Pre-Preg Laminates

Three standards have been issued for testing pre-preg laminating materials to provide a uniform basis for evaluation of characteristics and performance. Issued by the Pre-Preg Division of the Society of Plastics Industry, Inc., the standards govern test methods for determining resin and volatile content, flow and gel time of pre-impregnated materials for reinforced plastics and high pressure laminating.

Copies of the standards can be obtained from the society at 250 Park Ave., New York 17, N. Y.

Pre-pregs provide manufacturers and molders with a ready-to-mold reinforced plastic material which has the fabric or fibers already impregnated with resin. In conventional laminates, the resin and fabric are combined during the wet lay-up at the mold.

Plastics Technology Center

The Department of Defense has set up the Plastics Technical Evaluation Center (Plastec) at the Picatinny Arsenal, Dover, N.J., to serve military organizations and their contractors as a clearing house for information on plastics technology.

To keep abreast of latest developments in the plastics field, Plastec specialists will read technical literature available and make visits to plastics plants and laboratories.

Corrosion Papers Given At ASME New York Meeting

Eleven technical papers in the field of corrosion were presented during the Nov. 27-Dec. 2 annual meeting of ASME held in New York City. These papers were titled as follows: Vacuum Deaerator Design, Performance of Stainless Steel Condenser Tubes, Study of Sulfur Reactions in Furnace Deposits, Corrosion of Superheaters and Reheaters of Pulverized-Coal-Fired Boilers, Chemical Thermodynamics of Corrosion Products, Reactions of Magnesium With Inorganic Constituents of Heavy Fuel Oil and Characteristics of Compounds Formed, Slurry Spraying of Additives for Control of Corrosion and Deposits in Oil-Fired Boilers, Effect of Ammonia Injection on Corrosion in Air Preheaters, and New Developments in Handling Fuel-Oil Ash Corrosion Problem.

Qatar Pipeline Contract

The Qatar government has appointed Pencol Pipeline & Engineering Consultants of 19, Grosvenor Place, London, S.W. 1, as consulting engineers and designers for a gas pipeline system to be laid between the oil fields near Dukhan and Doha, the capital, where the gas will feed power stations, water distillation plants and other installations. The line will be about 50 miles of 10-inch pipe and about 10 miles of 6-inch pipe with a dehydration plant at Dukhan.

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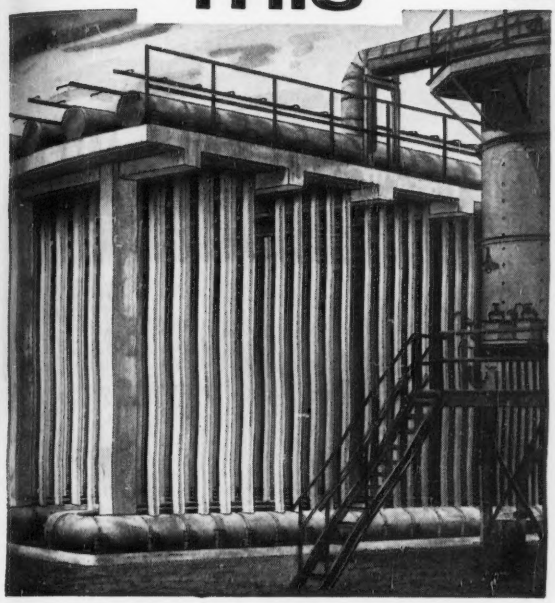
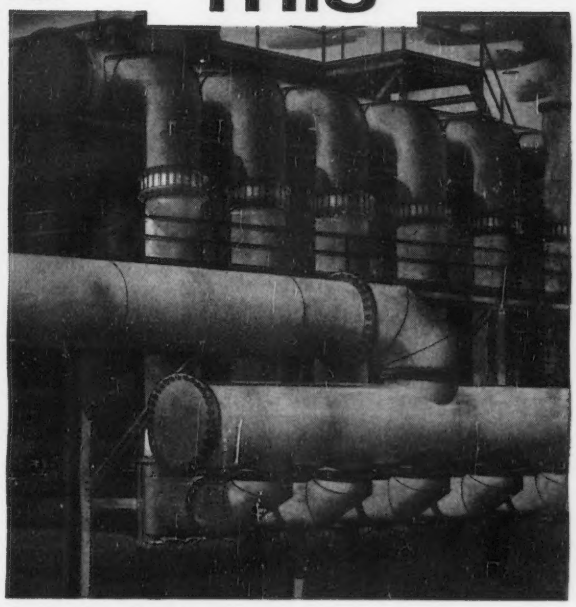




is corrosion-resistant

"KARBATE" IMPERVIOUS GRAPHITE HEAT EXCHANGERS!

Today, it doesn't make sense to sacrifice space, money, and minimum downtime by using heat exchangers not having the features of *unsurpassed corrosion-resistance, compactness, and low maintenance of "Karbate" impervious graphite exchangers.* Space was saved, piping simplified, and low maintenance was achieved when the "jungle" of single tube down-draft lead coolers (above left) was replaced by 6 compact "Karbate" shell and tube units (above right).

"Karbate" impervious graphite's high thermal conductivity and complete corrosion-resistance permit these heat exchangers to operate at higher velocities with associated increased heat transfer. This means that "Karbate" units with less surface area can thermally and economically replace larger metal exchangers in which high velocities produce localized accelerated corrosion. In such a case, "Karbate" exchangers with 83% less surface than carbon steel exchangers perform the same cooling job. And, at a total installed cost of approximately $10,000 less than the cost of retubing the corroded carbon steel exchangers with stainless steel tubes.

Actually, "Karbate" units offer unexcelled corrosion resistance at prices, in some instances, up to ⅓ less than many alloy and special metal units in which corrosion is measurable.

If you are considering a new heat exchanger installation, or if you have to replace or add to your present equipment, investigate the advantages of price, excellent corrosion-resistance, and trouble-free performance provided by "Karbate" impervious graphite shell and tube exchangers. For information, write National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

A 45" dia. "Karbate" shell and tube heat exchanger having 685 ⅞" I.D., 1¼" O.D. by 14' long tubes. It has an O.D. area of 3135 square feet.

"National", "Karbate" and "Union Carbide" are registered trade-marks for products of

NATIONAL CARBON COMPANY UNION CARBIDE

PLASTIC LININGS for pipeline were demonstrated with this machine at the NACE South Central Region Conference in Tulsa. Shown with the designer of the experimental model is C. F. Straughan of Perrault Interliner Co., Tulsa, Okla. The model forces a plastic liner into pipe by turning the liner inside inself with pressure. Fluids such as water or oil could be used, but compressed air was used for convenience at the demonstration.

Device Puts Plastic Tube Into Pipelines In-Place

An experimental model of a device for inserting a flexible plastic tubing inside a pipeline in-place was demonstrated during the South Central Region Conference held Oct. 25-27 in Tulsa, Okla.

At least two major problems remain to be solved before the device can be used commercially: An adequate plastic material for the lining and an adhesive that can be used to stick the lining to the pipe. The pipe must be cleaned before the liner can be applied.

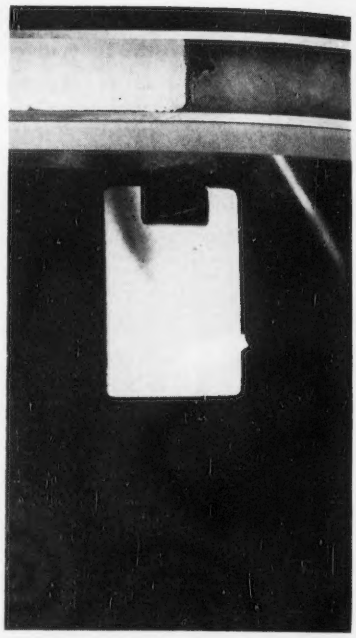
The interliner device consists of an air-tight chamber (see accompanying photograph) from which a flexible plastic tube is unrolled and forced through a nozzle connected to the pipe being lined. The open end of the tube is fastened inside the machine; the tubing is extruded from the roll by a gas or liquid which pushes the tube inside-out onto the pipe wall. Polyethylene liner of 1.5 mil thickness was used for the demonstration.

Inventors of the interliner method are Richard V. Harper and Lawrence B. Wilder of Pan American Petroleum Corporation. Perrault Interliner Company of Tulsa, Okla., has been assigned manufacturing rights. The demonstration at the Tulsa Conference was given by C. F. Straughan of Perrault, who designed the experimental model.

Simplicity of the experimental model is illustrated in the fact that it was designed and fabricated for use at the conference only five weeks after Perrault received manufacturing rights on the machine.

Although the demonstration unit was designed for 2-inch line, 3 or 4-inch lines could be lined by changing the unit's nozzle to a larger size.

CORROSION'S ANNUAL INDEX is published in this issue (Facing Page 118)



CERAMIC-METAL composite material on the left section (top photograph) of the one-inch nickel base alloy pipe shows no damage after a 15-hour exposure to hydrogen chloride gas at 1200 F. The uncoated portion (right section of pipe) has distinct corrosion damage. Bottom section shows a metal coupon coated with this new material being subjected to an oxy-acetylene flame at 1600 F. This coupon was unaffected, but similar tests on molybdenum showed severe oxidization.

Cermet Coating Resists 1300 F Corrosion Attack

A new material of construction made by bonding a ceramic-metal composite to base metals has shown resistance to impact and corrosion for use in chemical, nuclear and space applications.

This new material has resisted attack by corrosive vapors at 1300 F, a temperature that would destroy metals in a few minutes under the same conditions. The material also has been tested for such process equipment as small reaction vessels and heat exchanger tubing.

Top section of the accompanying photograph shows a high temperature corrosion test on a one-inch nickel base alloy pipe. Half of the pipe was coated with this new ceramic-metal material. After 15 hours' exposure to hydrogen chloride gas at 1200 F, the uncoated portion (right side of photograph) showed distinct corrosion; the coated section was not appreciably affected.

Bottom section of the photograph shows a coupon of metal coated with the new material being subjected to oxyacetylene flame at about 1600 F for five minutes. This coupon was unaffected, but tests on molybdenum coupons showed severe oxidation.

This ceramic-metal composite coating is called Nucerite, developed by the Pfaudler Co., a division of Pfaudler Permutit Inc., Rochester, N. Y.

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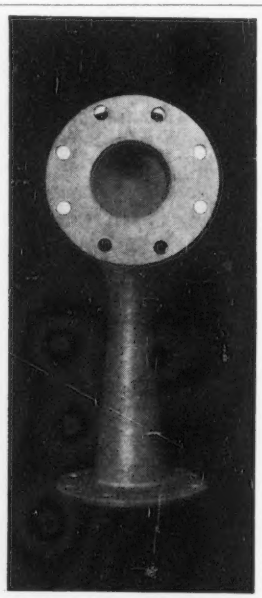
American supermarkets serve 200 million customers each week and stock an average of 8000 items.

Du Verre Completely Controls Corrosion in New S&K Gas Scrubbers



Now du Verre resin bonded fiberglass construction adds superior corrosion resistance to Schutte and Koerting's efficient Ejector-Venturi Scrubbers. Widely used throughout the process industries, SK 4010 units move large quantities of air and gas at low draft. They effectively remove dust and particulate matter, obnoxious vapors and corrosive gases.

Besides complete corrosion control, du Verre construction offers many other important advantages: Unlike lined equipment, venturi and jet can be accurately machined for more efficient operation. Erosive action of the high velocity venturi jet is minimized, even at temperatures approaching 300° F. High strength coupled with low weight eases handling and installation. The need for elaborate supporting steel is eliminated. Complete corrosion resistance on both exterior and interior surfaces eliminates need for painting and maintenance.

Investigate the many advantages of du Verre corrosion-resistant ducts, stacks, hoods, tanks, trays and specially-fabricated process equipment.

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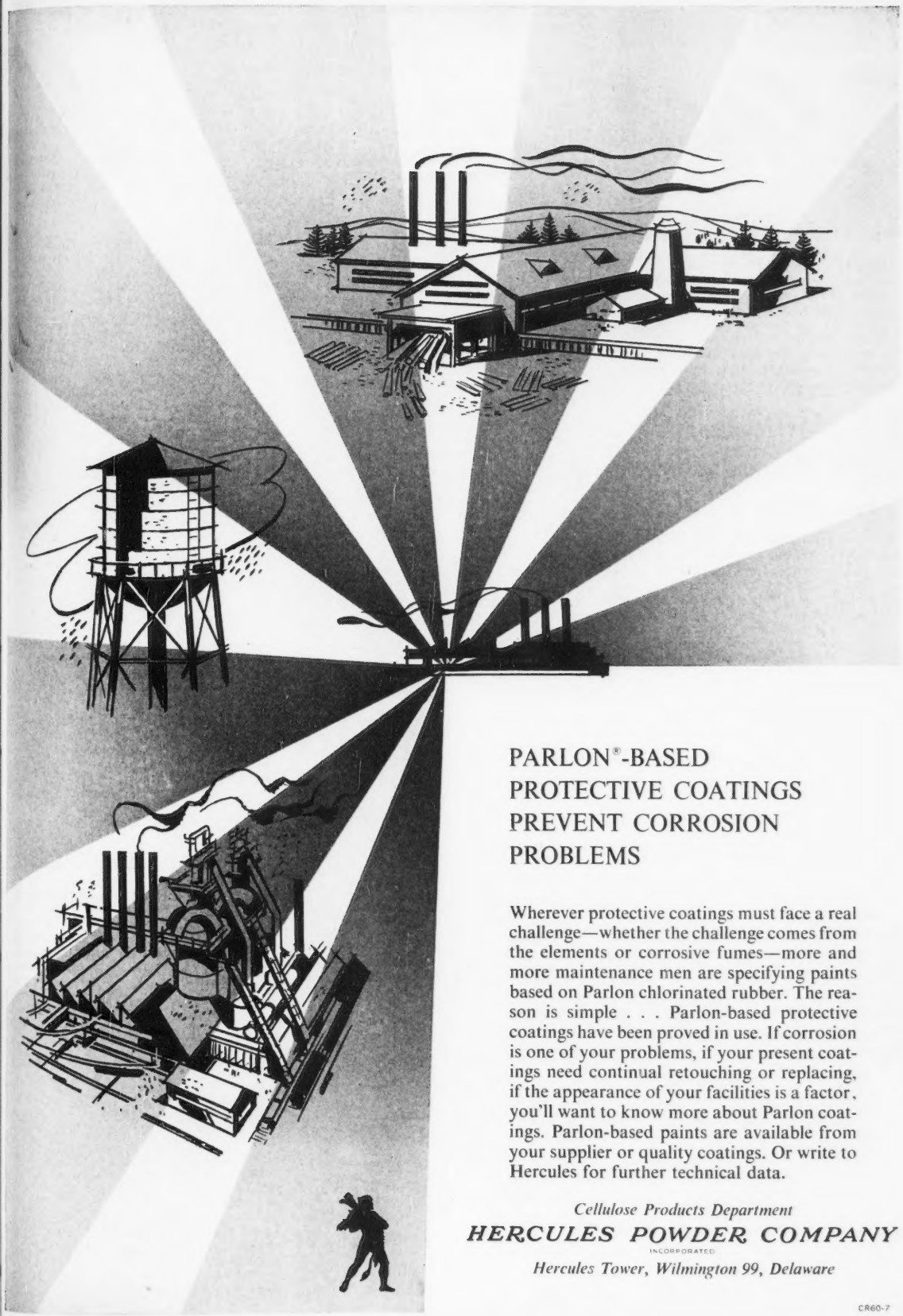

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PREVENT CORROSION
PROBLEMS

Wherever protective coatings must face a real challenge—whether the challenge comes from the elements or corrosive fumes—more and more maintenance men are specifying paints based on Parlon chlorinated rubber. The reason is simple . . . Parlon-based protective coatings have been proved in use. If corrosion is one of your problems, if your present coatings need continual retouching or replacing, if the appearance of your facilities is a factor, you'll want to know more about Parlon coatings. Parlon-based paints are available from your supplier or quality coatings. Or write to Hercules for further technical data.

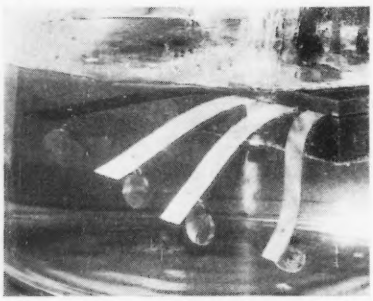
Cellulose Products Department

HERCULES POWDER COMPANY

INCORPORATED

Hercules Tower, Wilmington 99, Delaware

CR60-7



HIGHER TEMPERATURE resistance is claimed for a new polyvinyl dichloride which can be extruded into piping for use in industrial hot acid service. Sample of the new plastic on the left shows no sag in the test exposure to 180-degree water. The other strips (left to right) are polyamide, high density polyethylene and conventional vinyl.

New Plastic Resists Higher Temperatures Than Other Vinyls

A new polyvinyl dichloride plastic that can withstand temperatures 60 degrees higher than conventional vinyls has been developed for use as industrial hot acid piping and household hot water plumbing.

Called hi-temp Geon, the new plastic has the same qualities of strength, light weight, impact resistance, non-flammability and corrosion resistance of vinyls to strong alkalies, acids and a variety of other chemicals.

Cost of piping made of this new plastic is estimated to be competitive with existing pipe products.

The accompanying photograph shows strips of conventional vinyl, high density polyethylene and polyamide sagging in an exposure to 180-degree water. The sample of polyvinyl dichloride at the far left shows little sag.

In one industrial trial, hi-temp Geon passed tests in an exposure to 90 percent sulfuric acid at 185 F for 30 days.

This pipe can be joined with socket joints cemented with solvents or by threaded couplings and can be cut with an ordinary saw. Curves can be formed by heating.

This new plastic is compounded to withstand operating temperatures from 180 to 200 F at pressures to 150 psi. It can be molded, extruded and heat-formed on standard plastic processing equipment, according to the B. F. Goodrich Chemical Co., 800 Second Ave., New York 17, N. Y., developer of the new plastic.

BOOK NEWS

Corrosion Problems of the Petroleum Industry. S.C.I. Monograph No. 10. 234 pages, 5½ x 8½, cloth. October 3, 1960. The Macmillan Co., 60 Fifth Ave., New York 11, N.Y. Per copy $6.

Papers and discussions presented at a joint meeting organized by the Institute of Petroleum, the Corrosion Group and the Chemical Engineering Group, 26-27 Nov., 1959 at Federation of British Industries, London.

The nine papers are divided into four sessions and topics covered are petroleum production equipment, marine structures, tanker hulls, storage tanks and pipelines, tubular heat exchange equipment, installations using salt water, non-destructive testing, and metallic and non-metallic materials. The discussions are voluminous and complete.

There are alphabetical subject and author indices.

The Sigma Phase Problem in Stainless Steels. By John F. Eckel. 15 pages, 6 x 9, paper. June, 1960. Bulletin of the Virginia Polytechnic Institute, Blacksburg, Va. Periodical, cost not indicated.

A literature survey of the subject made under contract from the Metallurgy Division, Oak Ridge National Laboratory. 32 references.

Air Pollution. Sec. I, Pub of R.A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio. 24 pages, 8½ x 11, paper. July 1, 1960. U.S. Dept. Health, Educ. & Welfare, Div. Engineering Services. Free on request.

A list of about 85 publications, training manuals and reports. Includes two order forms for copies of publications which are available free, as long as supply lasts.

Tinplate Testing. 55 pages, 6 x 9¼ inches, paper. By W. E. Hoarse and S. C. Briton. May, 1960. Tin Research Institute, Inc., 492 W. Sixth Ave., Columbus, Ohio. (Also available from all offices of Tin Research Institute). Free.

A comprehensive treatise on the subject. Principally for those in tinplate industry concerned with performance and quality of plated materials including tests for rust resistance, staining, and other qualities. There are 24 illustrations and diagrams. There are six general and 18 literature references.

Handbuch fur den Rostchutzanstrich. In German. By Lorenz Biener. 314 pages, 5½ x 8¾ inches, flexible plastic. 1960. Published by Curt R. Vincentz, Schliessfach 8, Hanover, Germany. Per copy, DM 22.5.

A comprehensive treatise on the use of industrial coatings. The 51 literature references are all of Eurogean origin.

Contents include causes of corrosion and prevention by coatings, preventive measures against rust and efficient paint use, paint preparation, questions on proper application, paint proposals and quotations, economic aspects of coating costs;

Requirements for coatings, devising a coating system, problems associated with good protection, principal mistakes and how to avoid them, formulas, durability and guarantees.

Conclusions are stated in a separate chapter.

There is an alphabetical subject index.

LET *Coreco* WORK FOR YOU 24 HOURS A DAY TO PROTECT YOUR OFFSHORE EQUIPMENT AGAINST COSTLY CORROSION . . .

Two-fisted Coreco protection pays for itself many times. Whether your problem is better solved by rectifiers or magnesium anodes, our engineers have the knowledge to determine lowest overall installation and operating costs. It costs you nothing to check with Coreco engineers.

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HOUSTON 36, TEXAS

$25,000 Awards Offered In Arc Welding Contest

Awards totaling $25,000 are being offered by the James F. Lincoln Arc Welding Foundation for the best papers explaining how efficient application of arc welded steel has contributed or can contribute to progress in the design of a machine or structure.

Awards will be made in two, non-competing divisions: machines and structures. All papers must be mailed on or before July 17, 1961.

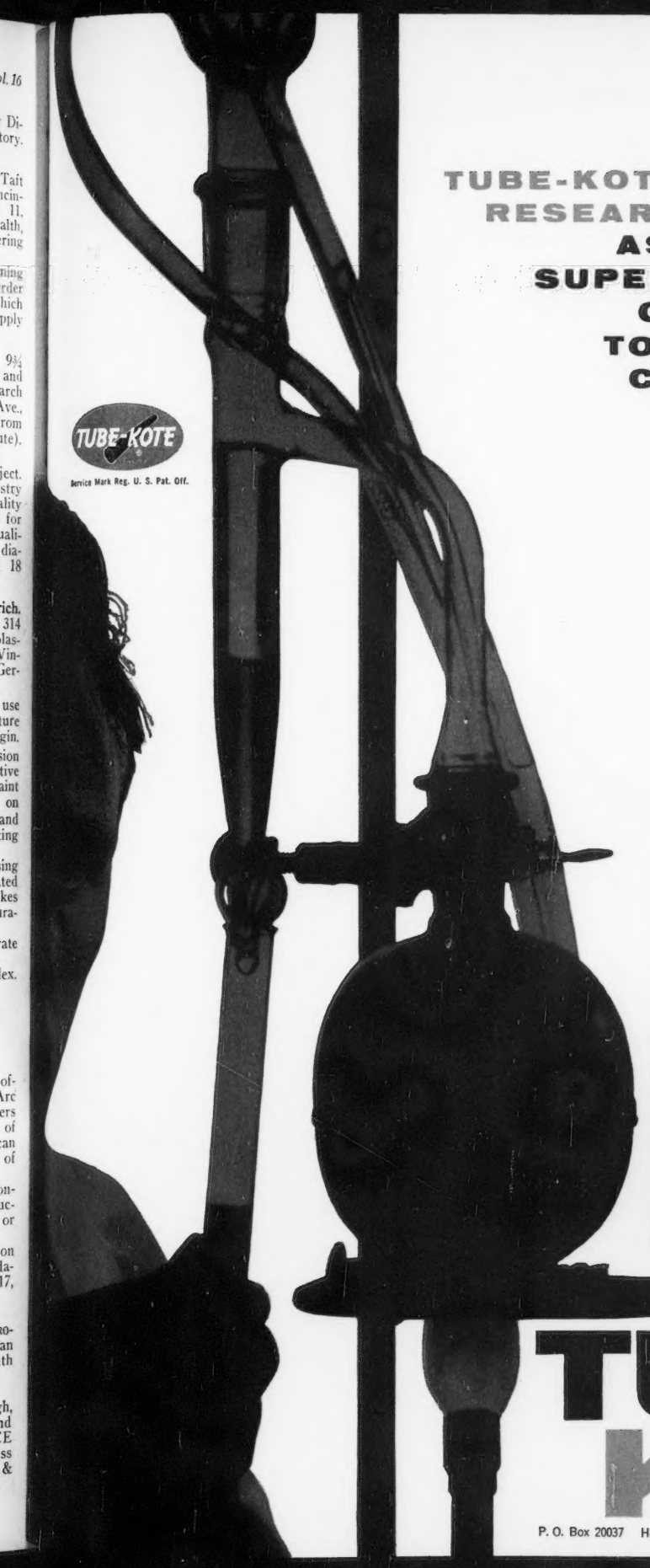
A brochure giving complete details on the contest is available from the foundation at P. O. Box 3035, Cleveland 17, Ohio.

•

News intended for publication in CORROSION should be in Houston no later than the 10th of the month preceding month of publication.

•

Lapel pins approximately 7/16 inches high, made of gold with inlaid red enamel and a ruby center, are available to NACE members only. Price is $10. Address orders to Executive Secretary, 1061 M & M Bldg., Houston 2, Texas.



TUBE-KOTE

Service Mark Reg. U. S. Pat. Off.

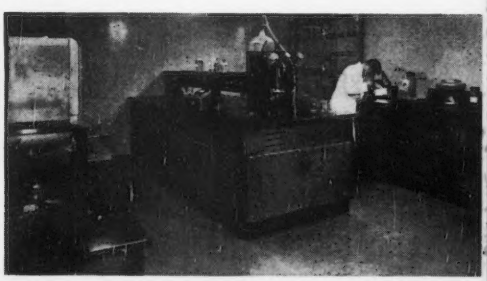
TUBE-KOTE RESEARCH ASSURES SUPERIOR COATINGS TO STOP CORROSION

When you specify Tube-Kote, you have every right to expect a far superior coating.

Tube-Kote's outstanding success in preventing corrosion is a result of constant and careful attention to many details. Ingredients must be blended within minute tolerances. Preparation of the metal must be carried on under strict supervision and inspection. Application must be made under near perfect conditions, and curing must be precise to meet the harsh requirements of production use.

Only Tube-Kote has a research department to provide laboratory control over every step in the plastic coating process. Tube-Kote research has pioneered the development of new and better coatings for specialized uses.

Tube-Kote Research and Superior Methods Bring You More Durable Coatings and Faster Service... at Lower Cost



TUBE-KOTE®

INC.

P. O. Box 20037 Houston 25, Texas • Branch Plants: Harvey, Louisiana; Midland, Texas

Cleaners

About 2500 blows per minute for chipping scale, rust or weld spatter are claimed as one feature of an electric power hammer made by Ingersoll-Rand Co., 11 Broadway, New York 4, N.Y. Weighing just over 11 pounds, the hammer is practical for overhead cleaning jobs. Accommodating drills to 1⅛ inch diameter hole size, the hammer can be ordered with 115 or 220 volt motors.

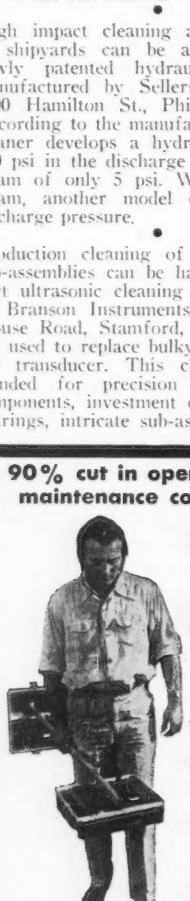
•

High impact cleaning aboard ships and at shipyards can be accomplished with newly patented hydraulic jet cleaners manufactured by Sellers Injector Corp., 1600 Hamilton St., Philadelphia 30, Pa. According to the manufacturer, one model cleaner develops a hydraulic pressure of 100 psi in the discharge stream with inlet steam of only 5 psi. With 150 psi inlet steam, another model develops 630 psi discharge pressure.

•

Production cleaning of small parts and sub-assemblies can be handled by a compact ultrasonic cleaning system developed by Branson Instruments, Inc., 40 Brown House Road, Stamford, Conn. Transitors are used to replace bulky vacuum tubes in the transducer. This cleaner is recommended for precision parts, electronic components, investment casting, miniature bearings, intricate sub-assembles, dies and similar products from which various soils or contaminants must be removed.

90% cut in operating and maintenance cost means



CASH in the BANK for you!

New, transistorized

M-SCOPE PIPE FINDER only $189.50

Rugged, transistorized construction practically eliminates maintenance costs . . . extends battery life to a year or more. Pinpoint accuracy, greatest depth penetration make the M-scope first choice in the field!

Heavy Duty LEAK DETECTOR $295.00

Send for FREE 1960 Catalog

FISHER

Research Laboratory, Inc.

Dept. CO-3, Palo Alto, Calif.

Coatings, Metallic

Increased coating adherence for non-electroplated copper coatings is claimed for Cuprodine No. 5 process, developed by Amchem Products, Inc., Ambler, Pa. It is currently used in the treatment of tire bead wire and wire strength members before molding and vulcanizing. The copper coating provides a bonding surface for the rubber.

•

New high speed selective plating process that permits use of such unusual metals as binary or ternary alloys is described in a brochure available from Selectrons, Ltd., 520 Fifth Ave., New York 36, N.Y. Called the Selectron process, it includes a special rectifier, metallo-organic solutions and a variety of styluses to achieve dense deposits on any base metal. The process is designed for selective electroplating of parts on an article which need metal build-up.

•

Zincate immersion compound for coating aluminum work with a tightly bonded film of metallic zinc before electroplating with other metals has been developed by the Diversey Corporation, 1820 West Roscoe St., Chicago 13, Ill. Designated ZN-77, the compound is designed to be used at lower concentrations and give faster drainage of solution from processed parts with greater tolerance to temperature variations, according to the manufacturer.

Instruments

Thicknesses of coatings on iron and steel can be gaged with the Type ES Permascope, developed by Twin City Testing Corp., 533 South Niagara St., Tonawanda, N.Y. The instrument is designed to provide a non-destructive method of measuring thicknesses of organic and non-magnetic metal coatings (including phosphate) with the accuracy of the microscopic method. Accessories are available for measuring plating thicknesses on inner walls of tubing, pipe and cylinders with a minimum ID of 11/16-inch, at any point within the bore, according to Twin City engineers.

•

A voltmeter shunt designed to fit permanently into meter case lids adapts the instrument for testing current on cathodic protection systems when the amperage exceeds 5.0 amperes. The shunt is a 50 ampere (maximum) 100 millivolt type and is five inches long.

•

An electro-pneumatic converter that converts a d-c voltage or current into a pneumatic pressure signal has been developed by Hagan Chemicals & Controls, Inc., Hagan Center, Pittsburg 30, Pa. Called the PowrMag Converter, is statically and dynamically balanced to resist shock and vibration and has temperature compensation to maintain accuracy over a variety of temperature conditions.

•

Location of holidays in coatings of buried pipe can be made with a new portable detector, according to Pipetron Company, 12926 Saticoy St., North Hollywood, Cal., manufacturer of the instrument. Consisting of a transmitter, receiver, search coil and other accessories, the detector is designed to locate holidays on pipe coatings buried several feet deep. It also can be used to locate pipe and shorts between a protected line and other pipe.

Metals, Non-Ferrous

Production of vanadium pentoxide, a heat and corrosion resistant metal, is being undertaken in a joint operation by Minerals Engineering Co., Grand Junction, Colo., and Susquehanna-Western, Inc., Denver. A new process will be used to chemically extract vanadium from vanadium-bearing slag, a wasted by-product of phosphorous operations.

•

Wire springs for operations at temperatures to 1800 F are being made of a vacuum melted nickel-base alloy designated Rene' 41, developed by National-Standard Company, Niles, Mich. Typical applications will include missiles, electronics, rockets and nuclear equipment.

•

Materials for use in extreme heat, abrasic action, corrosion and other problems are discussed in the quarterly issue of "Advanced Materials Technology," published by the Carborundum Co., Niagara Falls, N. Y.

•

Large titanium diboride shapes are being produced by the National Carbon Company, division of Union Carbide Corporation, 100 E. 42nd St., New York 17, N.Y. Cylinders 6 inches in diameter, 20 inches long weighing 100 pounds and 14 inches in diameter, 10 inches long, weighing 260 pounds have been produced. Having high temperature strength, this material can be used for abrasion resistant surfaces such as wear plates, knife edges, sandblasting or shotblasting nozzles, metal spraying equipment and dies for wire drawing.

•

Molybdenum-tungsten alloy powders newly developed for production of true solid-solution alloy products are available from the Chemical and Metallurgical Division of Sylvania Electric Products Inc., 730 Third Ave., New York 17, N. Y. These powders are produced by hydrogen reduction of the oxides or ammonium compounds of molybdenum and tungsten.

Non-Metallics

Synthetic mica paper with a melting temperature of 1365 C and an operating temperature to 1000 C for use in high temperature transformers, motors and capacitors is available from Synthetic Mica Company, a division of Mycalex Corporation of America, Clifton, N. J. The paper is available in continuous strips three inches wide or in sheets to six inches in diameter with a thickness range from 0.002 to 0.007 inch.

•

New rubber-like materials have been created in studies to develop radiation

resistant rubber. Acrylic monomers containing aromatic groups are being used in these studies at B. F. Goodrich Company's Research Center at Brecksville, Ohio. Research is expected to show how the location of an aromatic group in a polymer affects the degree of radiation protection.

Plastics

Environmental stress cracking resistance and temperature embrittlement resistance have been improved in a new type high density polyethylene, according to the producer, Goodrich-Gulf Chemicals, Inc., East Ohio Bldg., Cleveland 14, Ohio. Called Ameripol, this plastic will be produced at a new plant in Port Neches, Texas. Ameripol will be suitable for blow-molded articles, insulation for wire and cable and extruded pipe, according to Goodrich-Gulf reports.

•

Roof ventilators to blow corrosive fumes high in the air to minimize corrosion to nearby roofs and ground areas are being made of Rigidon by Heil Process Equipment Corp., 12850 Elmwood Ave., Cleveland 11, Ohio. This material is a glass reinforced unplasticized polyvinyl chloride. All exposed parts including the housing and impeller are made of plastic to resist corrosion.

•

A new type Teflon with one side cementable with common adhesives has been developed by Du Pont's Film Department, Wilmington, Del. The new FEP-fluorocarbon film type can be anchored with many standard adhesives to a variety of engineering materials for use as an anti-stick or protective surface. Practical applications using epoxy resins as bonding agents include liners for glass filament wound chemical and cryogenic fuel tanks and cylinders, ice-release coatings on aluminum trays and release cladding on heated or chilled processing rolls. When rubber adhesives are used, the new film type can be cemented as a liner for rubber and fabric hose and tubing and over rubber and asbestos for chemically resistant diaphragms and seals.

•

Plastic shelters for personnel or equipment that can be dropped by helicopters, floated ashore or dragged over rough terrain have been developed by the Perfection Division of the Hupp Corporation, 1135 Ivanhoe Road, Cleveland 10, Ohio. The shelters feature a monocoque sandwich construction enveloped by a stressed polyester resin, fiberglass laminated skin. They measure 12 by 7 by 7 feet and weigh 775 pounds, according to the manufacturer.

Pumps

A pressure primer elevator designed for dispensing heavy materials such as sealers, cements, mastics and certain adhesives has been developed by Lincoln Engineering Co., 4010 Goodfellow Blvd., St. Louis 20, Mo. It is designed to be used with a five-gallon container. The elevator is an air operated unit requiring regulated air pressure.

•

Vertical centrifugal pumps of bronze and stainless steel construction for handling corrosive liquids are available from Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Philadelphia 30, Pa. They can be obtained in capacities from 50 to 600 gpm.

•

Reduced horsepower requirements are claimed for a new general purpose gear pump made of Du Pont's thermoplastic called Delrin. Tests show the plastic pumps reduced power requirements as much as 50 percent over comparable metal models, according to the manufacturer, Planet Products, Chicago 1, Ill. Operating advantages include low heat build-up and low noise level. The pumps have a capacity range from 2 to 18.5 gpm and are designed to operate at pressures to 100 psi with non-lubricating liquids.

•

Custom built jet pumps for air, gas or fluid ejection or mixing are made by Allen Aircraft Products, Inc., Ravenna, Ohio. The pumps are made from many materials. Aluminum models are used for corrosion resistance in transferring fuel from jettisonable wing tanks, to pick up fuel from remote tank pockets, to transfer abrasive fluids and to mix active chemicals. A small line of high pressure fluid pumped through the jet inducts the surrounding fluid to pump a large volume of fluid at lower pressure. Jet pumps have no moving parts and can be designed for gas-air flow and mixing, for reacting gas with liquids in chemical processing and for mixing dissimilar fluids.

•

A corrosion resistant transparent plastic head made of methyl methacrylate is one feature of a new electrically driven

(Continued on Page 36)

MID-AMERICA

BUILDS FOR ENDURANCE

Mid-America Pipeline Company's new line will carry LPG all the way from the West Texas and New Mexico area to Minnesota and Wisconsin—2,200 miles of pipe. A big job of construction. Big investment in money too! Pipelines must be built to last.

That's why Reilly Intermediate Enamel with Q. D. Primer, were specified as coatings for a portion of the Mid-America system to lend lifelong protection against corrosion to the new line. Coal Tar Enamels are the engineering materials of choice where endurance of protection against corrosion is a design requirement.

Reilly COAL TAR PRODUCTS

ARMED Protective Coatings

REILLY TAR & CHEMICAL CORP.

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REPUBLIC ELECTRUNITE
"DEKORON-COATED" E.M.T.

COMBATS CORROSION

Republic ELECTRUNITE® "Dekoron®-Coated" Electrical Metallic Tubing combats corrosion in atmospheres that destroy ordinary conduit.

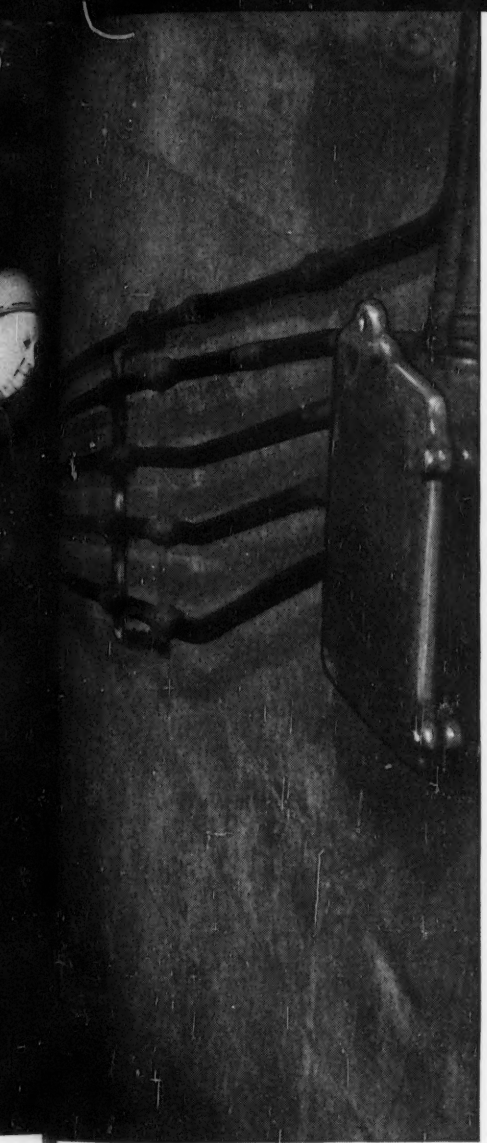
"Dekoron-Coated" E.M.T. is a plastic-armored steel electrical raceway that resists fumes, dust, gases, and chemical action of corrosive service. Every length is fully protected from end-to-end by armor-tough, corrosion-proof polyethylene applied over the galvanized finish.

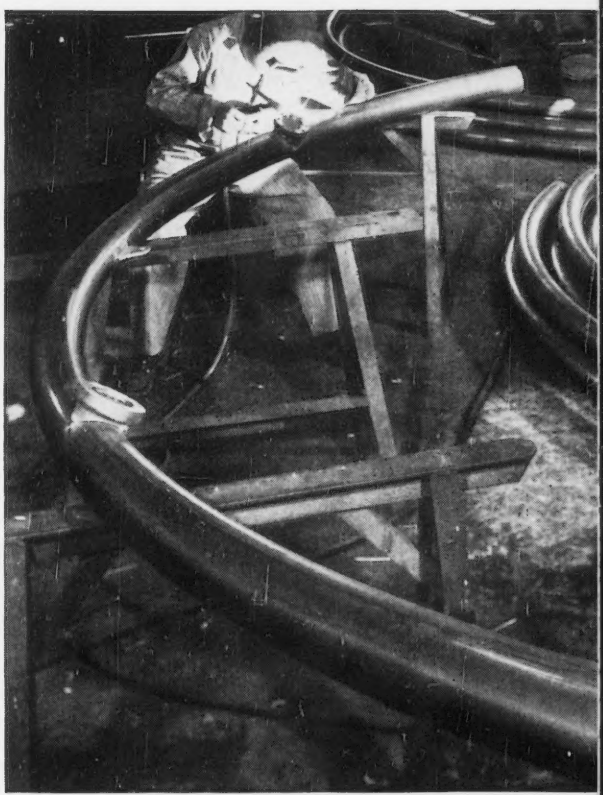
One major industry experienced trouble in their coke conveyor gallery where a strong concentration of ammonia still waste fumes corroded standard conduit, resulting in costly "down" time —and required continual conduit replacement.

"Dekoron-Coated" E.M.T. and rigid steel conduit is now resisting these attacks. And after 18-months service, is still practically new.

For complete information, call your Republic representative, or write direct. Send coupon below.

PLASTIC-COATED STEEL PIPE—REPUBLIC X-TRU-COAT—more than meets requirements of most severe corrosion applications. You can bury it in soils of different potentials, subject it to stray currents, lay it in the most aggressive soil. X-TRU-COAT Plastic-Coated Steel Pipe is available in a wide range of wall thicknesses and diameters (through 5⁹⁄₁₆″ O.D.). Call your Republic representative for complete details and specifications. Or, write today. (X-TRU-COAT is produced under the Dekoron process.)





REPUBLIC ELECTRUNITE STAINLESS STEEL TUBING resists salt-corrosion, is easy to fabricate. Non-magnetic and salt corrosion-resistant ELECTRUNITE Stainless Steel Tubing was used to fabricate corona rings for a powerful East Coast Navy Radio Station. Despite the rather severe bend of the 15- and 20-foot rings, the fabricator reported no trouble whatsoever. ELECTRUNITE Stainless Steel Tubing and Pipe are available in A.I.S.I. chrome-nickel analyses. Tubing sizes from ⅜″ O.D. to 5″ O.D. Pipe sizes from ⅛″ I.P.S. to 2″ I.P.S. in schedule 40S, from ⅛″ I.P.S. to 4″ I.P.S. in schedule 10S, and from ½″ I.P.S. to 4″ I.P.S. in schedule 5S wall thicknesses. Call your Republic representative, or write for specifications.

REPUBLIC GALVANNEALED SHEETS SOLVE CORROSION PROBLEM in Kathabar® units manufactured by Surface Combustion Corporation. Units are designed to lower or raise the relative air humidity through evaporation or absorption of moisture. Republic Galvannealed, used for coil tube sheets, takes all forming operations. Corrosion and rust problems are held to an absolute minimum. Write for more information.

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World's Widest Range of Standard Steels and Steel Products

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☐ Republic ELECTRUNITE "Dekoron-Coated" E.M.T.
☐ Republic X-TRU-COAT Steel Pipe ☐ Galvannealed Sheets
☐ Republic ELECTRUNITE Stainless Steel Tubing and Pipe

Name_____ Title_____

Firm_____

Address_____

City_____ Zone____ State_____

NEW PRODUCTS

(Continued From Page 33)

positive displacement chemical proportioning pump made by B-I-F Industries, Inc., 345 Harris Ave., Providence, R.I. The pumps are designed for accurate proportioning of chemical solutions, acids and alkalies to process water in industry. The design also includes a Hypalon diaphragm and check valves and a straight-through flow.

Research

Haveg Industries, Inc., Wilmington 8, Del., has completed its new research and development laboratory facilities at 336 Weir St., Taunton, Mass. The new research facilities will be used in all types of engineered plastics and plastic molding such as injection, compression, transfer, blow and extrusion.

•

New research center for A. O. Smith Corporation, Milwaukee, Wis., is planned for completion by the middle of 1961. The new laboratories will be devoted to advanced fields in solid state physics, physical chemistry of materials and energy processes involved in use of such materials.

Valves

Standard-Southern Corporation, 1801 Lyons, Houston, Texas, has been appointed a distributor of Durco sleeveline valves. Durco valves also will be available from Standard-Southern branches in New Orleans, Beaumont, Odessa and Dallas.

•

Instrument plug valves with sleeves made of polytetrafluoroethylene are available from Continental Manufacturing Co., 230 Park Ave., New York 17, N. Y. The valves have screwed ends, are available in sizes from ¼ to 1 inch and are recommended for on-off use on rated pressures within temperatures from —50 F to 400 F with gas or liquid and corrosive or non-corrosive media.

•

External adjustment to maintain constant regulated flow regardless of variations in pressure is one design feature of a new cartridge type low capacity flow regulator made by Fluid Regulators Corporation, 313 Gillette St., Painesville, Ohio. The regulators are constructed of stainless steel and anodized aluminum for corrosion resistance.

•

About $200 million was spent on classical phonograph records during 1959 in this country.

•

About $15 million worth of Christmas tree light bulbs were purchased in the United States for the 1959 Yuletide season.

MEN in the NEWS

James C. Gray, administrative vice president of raw materials with U. S. Steel Corp., Pittsburg, Pa., was elected 1961 president of the Society of Mining Engineers, a constituent organization of AIME.

•

Walter Hanstein, Jr., has been appointed associate director of engineering for the Burroughs Corp., Detroit 32, Mich.

•

Eugene Jacobson has been elected a vice president of Sun Chemical Corp., 730 Third Ave., New York 17, N.Y.

•

William A. Klawitter has been appointed supervisor of magnetic and expansion alloys research for Carpenter Steel Co., Reading, Pa.

•

NACE Member **Stanley B. Lord** has been named senior inspector and **Stanley L. Clewett** made field engineer in the Construction and Inspection Section of Pittsburgh Chemical Co., Grant Bldg., Pittsburgh 19, Pa. **Salvatore A. Amelio** has joined the company as an engineer in the Project Section.

•

Ronald R. McNaughton, manager of the metallurgical division of Consolidated Mining and Smelting Company of Canada, Ltd., P. O. 1030, Place D'Armes, Montreal 1, Canada, has been elected the 1961 president of AIME.

•

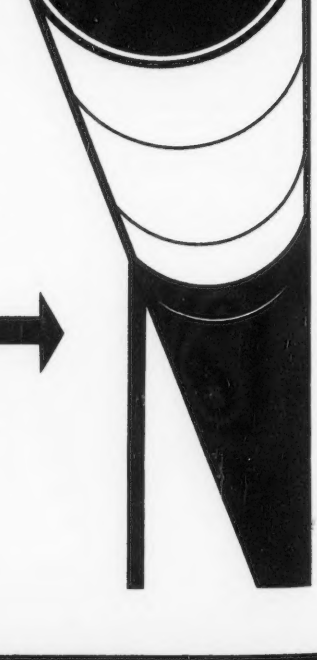
Thomas A. Marshall, Jr., has been

A TOUGH COMPETITOR...IN PRICE...
QUALITY...CORROSION CONTROL

In the never-ending battle against higher installation and maintenance costs for America's pipelines, Kermac's low-price, high-quality Outerwrap is furnishing the answer to these problems for more and more pipeline operators.

A pioneer developer of glass wraps, Kermac offers the maximum in adaptability, economy and long life — **and a visit with your Midwestern representative will show you why.**

Get the facts about **Kermac Outerwrap** NOW — **you may need it sooner than you think!**



KERMAC OUTERWRAP
FOR GAS AND OIL PIPELINES

MIDWESTERN
PIPE LINE PRODUCTS CO.
4645 Southwest Blvd. Tulsa, Okla. HI 6-6144
Cable Address: Mid Pipe

elected executive secretary of ASTM, 1916 Race St., Philadelphia 3, Pa.

•

Norman A. Morella has been appointed project engineer with Hill Hubbell Co., 3091 Mayfield Rd., Cleveland Heights 18, Ohio.

•

NACE Member **Charles C. Nathan,** group leader of the production chemistry research group at Texaco's Laboratories at Bellaire, Texas, has been issued a U. S. patent covering improvements in prevention of paraffin deposition.

•

B. F. Ollman, Jr., has been appointed sales engineer and district manager of the Philadelphia district for General Alloys Co., P. O. Box 2714, Philadelphia 20, Pa.

•

P. W. Perdriau has been named president of the B. F. Goodrich Industrial Products Company, Akron, Ohio.

•

Howard H. Sheppard, vice president of the Utilities and Power Department of Rumsey Electric Co., 7430 Sprague St., Philadelphia, Pa., has been eletced vice president of AIEE.

•

John S. Smart, Jr., general sales manager of American Smelting and Refining Co., 120 Broadway, New York 5, N.Y., has been elected 1961 president of the Metallurgical Society of AIME.

•

Ivan H. Smith has been named plant manager for Graver Tank & Mfg. Company's plant at 4809 Tod Ave., East Chicago, Ind., a division of Union Tank Car Company.

•

J. F. Stanners has succeeded **J. C. Hudson,** who has retired from his position as head of Corrosion Research in the Chemistry Department of the British Iron and Steel Research Association, 11 Park Lane, London, W. 1.

•

Alden P. Taber has been elected a vice president of Babcock & Wilcox Co., 161 E. 42nd St., New York, N.Y.

•

H. Nelson Versoy has been promoted to general superintendent of the pipe coating division of the H. C. Price Co., Bartlesville, Okla. **Leo C. Carle** will replace Mr. VerSoy as manager of the company's Gulf Division at Harvey, La. **Vernon J. Jones** has been promoted to plant superintendent at Harvey, La.

•

Jacob O. Whitlock, president of Midwest Prestressed Concrete Co., Springfield, Ill., was elected president of the Prestressed Concrete Institute. **Robert J. Lyman** of Atlas Structural Concrete, Inc., El Paso, Texas, was elected vice president and **Robert A. Matthews** of Precast Industries Inc., Kalamazoo, Mich., secretary-treasurer.

•

NACE member **William J. Arthur** is president of newly formed An-Cor Industrial Plastics, Inc., Riverside Industrial Center, Rano St., Buffalo, N. Y. The company is affiliated with the Arrow Tank Company, of which **Arthur P. Pfeil,** another NACE member, is president.

•

Spencer Chase has joined the Joseph Dixon Crucible Company of Jersey City, N. J., as sales representative in the Chicago-Milwaukee area.

•

Leo F. Collins has been named general superintendent of Detroit Edison's Central Heating Department, 2000 Second Ave., Detroit 26, Mich.

•

George Eggleston has been named chief engineer for Vapor Honing Co., Inc., 7018 Katy Road, Houston, Texas.

•

Hebert Fineberg has been appointed vice president and technical director for Glyco Chemicals, a division of Charles L. Huisking & Co., Inc., 417 Fifth Ave., New York 17, N. Y.

•

Thomas G. Giles, an NACE member has been appointed Chicago district manager for Royston Laboratories, Inc., Pittsburgh 38, Pa.

•

Mark V. Goodyear has joined Conap, Inc., Olean, N. Y., as manager of chemical development.

NACE member **Robert D. James** has been appointed manager of A. M. Byers Company's southwestern division with headquarters in the Mellie Esperson Bldg., Houston, Texas.

•

Peter Lillys has been appointed supervisor of Crucible Steel Company's Research Laboratory at Syracuse, N. Y.

•

Alfred E. Jones has been named assistant director of procurement for Koppers Company, Inc., Pittsburgh 19, Pa.

•

NACE member **Adrian J. MacNab** has joined the staff of Shell Development Company's Research Center at Emeryville, Cal., as an engineer in the materials engineering and corrosion department. **David K. Roe** has joined the department as a chemist.

(Continued on Page 38)

50%
more current output per anode

With Standard Magnesium High Current Anodes you get more ampere hours of protection per pound of metal consumed. And these anodes deliver 50% more current output than conventional anodes. Since four Standard Magnesium High Current Anodes will do the work of six conventional anodes, you save on initial as well as installation costs. Write today for our free booklet describing these anodes.

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Merry Christmas Happy New Year

standard pipeprotection inc.

3000 SOUTH BRENTWOOD BLVD. • ST. LOUIS 17, MO.

MEN in the NEWS

(Continued From Page 37)

Joseph C. Mohan has been appointed leader of the newly formed Coatings and Special Products Group of the Film Development Department at American Viscose Corporation, 1617 Pennsylvania Blvd., Philadelphia 3, Pa.

•

Gerald J. Naves, Jr., has been named eastern regional sales engineer for Technic, Inc., P. O. Box 965, Providence, R. I.

•

Harold W. Paxton, associated professor metallurgical engineering at Carnegie Institute of Technology, Pittsburgh, Pa., has been given the ASM $2000 Bradley Stoughton Award for outstanding young teachers of metallurgy.

•

Frank W. Reynolds, manager of IBM's Plastics Laboratory at Endicott, N. Y., has been elected 1961 president of the Society of Plastics Engineers. NACE member **John Delmonte,** president of Furane Plastics Co., Los Angeles, Cal., was elected a vice president of the society.

•

NACE member **Carle E. Johnson** has been promoted to head of laboratories at Nalco Chemical Company's Oil Products and Chemical Company's division, 6216 West 66th Place, Chicago 38, Ill. **Eugene O. Strauss** has been made manager of the division.

•

James R. Weiner has been appointed vice president of engineering for Philco Corporation's Government and Industrial Group, Tioga and C Streets, Philadelphia 34, Pa.

•

Joseph Whinney has been named to the Chicago district sales territory for the Riverside-Alloy Metal Division of H. K. Porter Company, Inc., Riverside, N. J.

•

John A. Wiedman has been appointed chief engineer for the industrial division of Hydromatics, Inc., 5 Lawrence St., Bloomfield, N. J.

•

Three NACE members have received "Certificates of Appreciation" at the recent API meeting in Chicago. They are **R. A. Brannon** of Humble Pipe Line Co., Houston, Texas, **E. E. Wickman** of Shell Oil Co., Los Angeles, Cal., and **Walter F. Rogers** of Gulf Oil Corp., Houston, Texas. The certificates were awarded for outstanding contributions to the oil industry. Mr. Brannon's and Wickman's awards were in the Division of Transportation; Mr. Rogers' was in the Division of Production.

•

Melvin Maddox, an NACE member, has been named manager of Allied Materials Corporation's newly formed Pipeline Coatings and Materials Division, 5101 N. Pennsylvania, Oklahoma City, Okla.

•

Jack W. Harris, former representative from NACE corporate member Rockwell Manufacturing Co., Pittsburgh, Pa., has been named industrial sales manager of Hydromatics, Inc., Bloomfield, N. J.

NACE NEWS

Compton

Copson

Compton, Copson To Receive 1960 NACE Awards

H. R. Copson of International Nickel Company's Research Laboratory, Bayonne, N. J., will receive NACE's 1960 Whitney Award to be presented during the 1961 NACE Annual Conference in Buffalo, N. Y., March 13-17. Kenneth G. Compton of Bell Telephone Laboratories, Inc., Murray Hill, N. J., will receive the 1960 Speller Award.

These two NACE awards are named for the original recipients who received the awards in 1946. The Willis Rodney Whitney Award is given in recognition of public contributions to the science of corrosion; the Frank Newman Speller Award is given in recognition of public contributions to corrosion engineering.

Mr. Copson, an NACE member since 1947, is author of nine technical papers published in CORROSION Magazine and has presented lectures at several NACE regional conferences and short courses. He also has written over 600 internal company reports and contributed chapters to several books on corrosion.

After receiving a BS from the University of Massachusetts in 1929 and a PhD in physical chemistry from Yale University in 1932, Mr. Copson was chief chemist of Apothecaries Hall Co., Waterbury, Conn., before joining International Nickel's Research Laboratory in 1934. He has been supervisor of the Laboratory's Corrosion Section since 1948.

He was awarded the ASTM Dudley Medal for a paper on the mechanism of rusting of steels in the atmosphere. His major fields of interest have been in galvanic corrosion.

Kenneth G. Compton, winner of the Speller Award, has been active in NACE since 1947. Author of 12 technical papers published in CORROSION Magazine, he has served as chairman of the Inter-Society Corrosion Committee and has been a member of several NACE technical committees.

Also active in ASTM, he currently is chairman of the advisory committee on corrosion and another committee on corrosion of non-ferrous metals. He has been active in the Electrochemical Society and American Electroplaters Society and is past chairman of the Gordon Research Conferences.

He joined Bell Telephone Laboratories in 1929 and is in charge of research and development engineering in the fields of corrosion, electroplating, wood preservation, casting resins, paint, electrolytic condensers, enameled wire and adhesives.

Mr. Compton has a BS and MS from Washington State University. During World War II he was a consultant to the Chief of Ordnance and to the National Defense Research Council. He was director of an Army Air Force Tropical Science Mission and served on advisory committees to the government. He has received two citations from the Navy for his contributions.

Polaris Missile Corrosion Control Among '61 Conference Topics

Such timely problems as corrosion control on the Polaris missile will be included in the variety of corrosion discussions scheduled for the 1961 NACE Annual Conference to be held March 13-17, Buffalo, N.Y.

The wide gamut of corrosion problems to be discussed at the conference is illustrated by the list of symposia: cathodic protection, chemical industry, general corrosion problems, marine, pipeline, plastics, coatings, utilities, elevated temperature, missiles, oil and gas and general corrosion principles.

Discussions at these technical symposia will cover not only the corrosion problem of various industries but also materials, techniques and methods to control corrosion which have been used by industry.

Technical Committee Meetings

Specific industrial corrosion problems also will be discussed at the 27 NACE technical committee meetings scheduled to date for the Buffalo conference. All conference registrants will be invited to attend these committee meetings.

1961 Corrosion Show

The 1961 Corrosion Show will be held in conjunction with the Buffalo conference. A wide diversity of corrosion control equipment, methods, processes and services will be displayed in over 100 booths at the conference headquarters in the Hotel Statler-Hilton. Qualified personnel from the exhibiting companies will be available to answer questions on corrosion control problems.

A list of the technical symposia for the conference with the chairmen of each symposium was published on Page 67 of the November issue of CORROSION.

Dates Are Set for Four Short Courses On Corrosion Control

Four corrosion control short courses sponsored or endorsed by NACE have been scheduled for the first six months of 1961. Three of the courses will be sponsored by NACE sections. Dates, locations and other information are given below on each.

Houston Short Course

The Houston Section's 7th annual short course will be held February 2-3 at the Rice Hotel, Houston, Texas. Appointments of group chairmen to head the various sessions are as follows:

M. E. Frank of Tennessee Gas Pipeline Co., corrosion control in transmission pipeline systems; J. T. Payton of Texaco, Inc., corrosion in oil and gas production; E. C. Winegartner of Humble Oil & Refining Co., corrosion in refineries and chemical plants; C. L. Woody of United Gas Corp., corrosion in utilities; and M. A. Riordan of Rio Engineering Co., corrosion in commercial and residential construction.

Shreveport Short Course

The annual corrosion short course sponsored by the Shreveport Section is scheduled for February 14-15 at Centenary College in Shreveport, La.

Buffalo Conference Advance Program

An Advance Program of the Buffalo Conference will be published in the January issue of CORROSION. This will include titles, authors and abstracts of technical papers to be presented and a listing of technical committee meetings to be held. An alphabetical list of the products to be on display at the Corrosion Show also will be given.

Appalachian Underground Short Course

The 6th Annual Appalachian Underground Corrosion Short Course endorsed by NACE will be held June 6-8 under the sponsorship of the University of West Virginia, Morgantown.

Greater Boston Short Course

A three-day short course in corrosion control under the sponsorship of the Greater Boston NACE Section has been planned for June 20-22. The course will be held at Wentworth Institute in Boston. W. S. Sanders of Algonquin Gas Transmission Company is chairman of the short course committee. J. R. Sarnosky of Westinghouse is program chairman.

Benson

Bishop

Brinkworth

Caldwell

Gleekman

Priest

Robinson

Seifert

Szymanski

Chairmen Complete Plans for 1961 Buffalo Conference

Chairmen of the various committees for the 1961 NACE Annual Conference to be held March 13-17 in Buffalo, N. Y., are making final arrangements for the meeting. Their conference responsibilities include the technical program, housing, registration, publicity, entertainment and the ladies' program. They are listed below.

General Conference Chairman: W. A. Szymanski of Hooker Electrochemical Co., Buffalo. His co-chairman is E. K. Benson of New York Telephone Co., Buffalo.

General Committee Chairman: R. E. Robinson of Hooker Chemical Corp., Buffalo.

Technical Program: D. K. Priest of Pfaudler-Permutit, Inc., Rochester, N. Y. His co-chairman is L. W. Gleekman of Wyandotte Chemical Corp., Wyandotte, Mich.

Reception: D. R. Bishop of Union Carbide Metals Co., Niagara Falls.

Registration: E. H. Caldwell of Hooker Chemical Corp., Niagara Falls.

Entertainment: R. E. Fonner of Rowe Products Inc., Niagara Falls.

Local Arrangements: W. J. Peters of John J. Gordon Co., Buffalo.

Housing: R. L. Seifert of Tennessee Gas Pipeline Co., Hamburg, N. Y.

Printing and Publicity: T. J. Brinkworth of Nukem Products Corp., Buffalo.

Ladies' Program: Mrs. E. K. Benson and Mrs. W. A. Szymanski.

Attention Librarians

and others who bind CORROSION by Volumes!

The index to CORROSION's 1960 (Volume 16) issues will include alphabetical subject and author references to the articles published in the Technical Topics Section. The growing number and importance of these articles makes necessary to include them in the indexing.

•

Those who bind CORROSION by volumes and who customarily extract Technical Section pages are reminded that it will be desirable to extract also the Technical Topics Section and add it to the Technical Section of each issue. Although the Technical Topics Section does not have cumulative numbering of pages, it will be relatively easy to locate articles if this procedure is followed.

NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1961

March 12—NACE Board of Director's Meeting, Hotel Statler, Buffalo, N. Y.

March 13-17—17th Annual Conference and 1961 Corrosion Show, Buffalo, N. Y., Hotel Statler.

March 17—NACE Board of Director's Meeting, Hotel Statler, Buffalo, N. Y.

Oct. 4-6—Western Region Conference, Hotel Multnomah, Portland, Oregon.

Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.

Oct. 24-27—South Central Region Conference and Exhibition, Shamrock-Hilton Hotel, Houston.

Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.

Southeast Region Conference, Miami, Fla., in conjunction with Miami Section's short course.

1962

March 19-23—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.

October 1-4—Northeast Region Conference, Hotel Sheraton Ten Eyck, Albany, N. Y.

October 9-11—North Central Region Conference.

October 11-12—Southeast Region Conference, Birmingham, Ala.

October 16-19—South Central Region Conference and Exhibition, Granada Hotel, San Antonio.

SHORT COURSES

1961

February 2-3—7th Annual Houston Section Corrosion Control Short Course, Rice Hotel, Houston, Texas.

February 14-15—Shreveport Section Corrosion Short Course, Centenary College, Shreveport, La.

June 6-8—6th Annual Appalachian Underground Corrosion Short Course, University of West Virginia, Morgantown.

June 20-21—Greater Boston Section Corrosion Short Course, Wentworth Institute, Boston, Mass.

Canadian Region

Montreal Section has no meeting scheduled for December. Next meeting will be January 10.

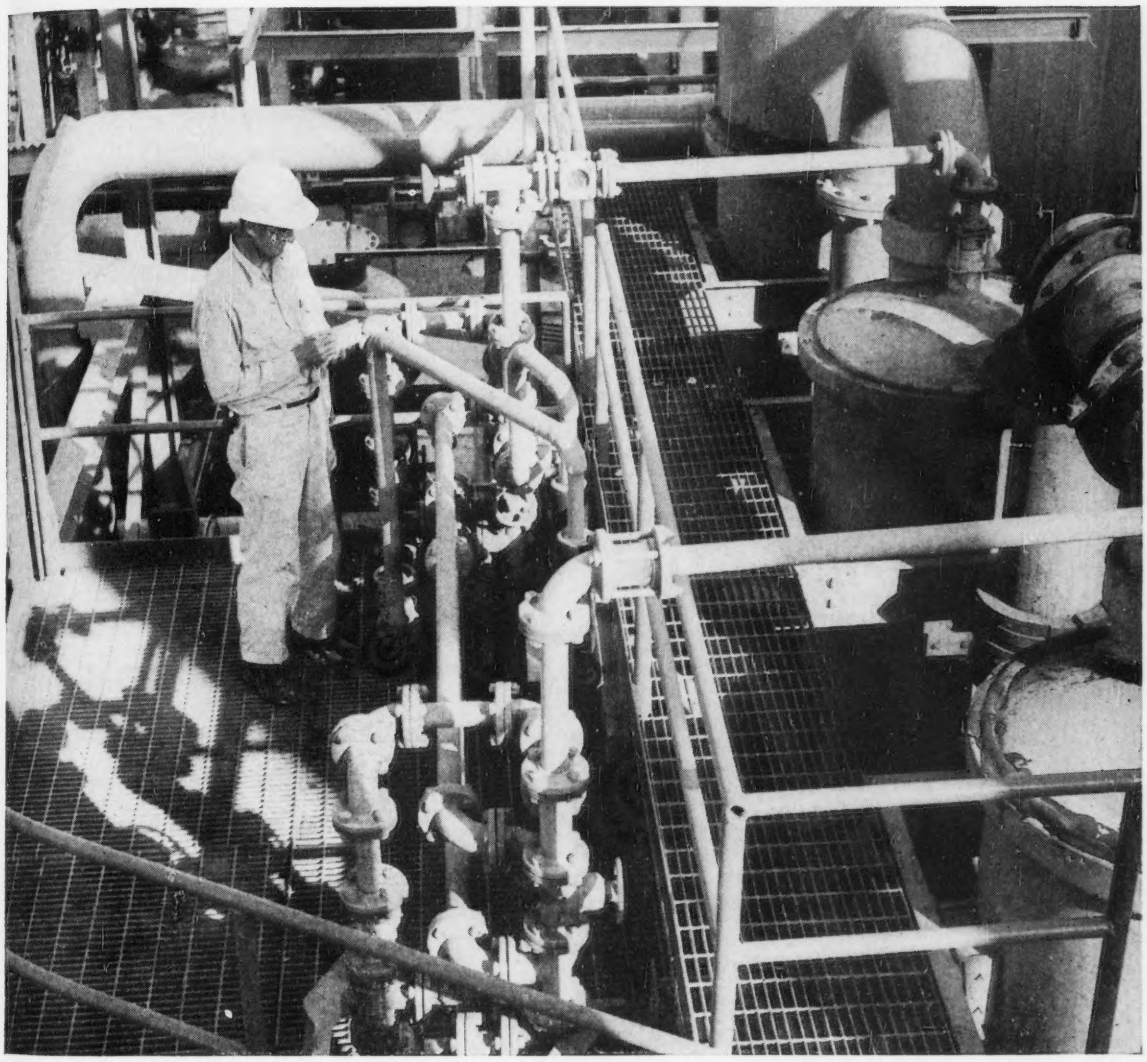
Robert Reese of Corning Glass Works spoke on the use of glass and silicates in the design of corrosion proof equipment at the October 11 meeting.

•

New Section being formed in the Ontario area held an October 31 dinner meeting with 32 members and guests present. Guest speaker was H. Webster of Corrosion Service, Ltd., Toronto, who spoke on road de-icing salts and automobile corrosion.

Temporary officers for the section are Chairman C. L. Easton, Vice Chairman E. G. Pauschenwein and Secretary-Treasurer T. Arneson.

DOW | SARAN LINED PIPE



After 16,000,000 Gallons of Sulphuric Acid

. . . No Corrosion in SARAN LINED PIPE

A vital round-the-clock stream of highly corrosive H_2SO_4 . . . to be carried by a piping complex that *must not* shut down for any reason . . . calls for the ultimate in corrosion resistance. Thanks to Saran Lined Pipe, the installation shown above has carried over 16,000,000 gallons of acid without a shutdown, or trace of corrosion, since construction a year ago.

At the Gramercy, Louisiana, plant of Kaiser Aluminum & Chemical Corporation, thirty gallons per minute of sulphuric acid are pumped through this three-inch Saran Lined Pipe into vertical tanks where newly generated chlorine gas is dried. Failure in these lines would shut down the entire caustic-chlorine plant, but the corrosion resistance of the Saran Lined Pipe permits uninterrupted operation, month after month.

Saran Lined Pipe, fittings, valves and pumps are available for systems operating from vacuum to 300 p.s.i., and from below zero to 200° F. They can easily be cut, fitted and modified in the field. For information write, Saran Lined Pipe Company, 2415 Burdette Ave., Ferndale, Mich., Dept. 2285 AU12

THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

AMCHEM Information Bulletin

Facts about pickling acid inhibitors

Nearly 40 years ago Amchem developed the first pickling acid inhibitor—RODINE—and with it revolutionized acid pickling. Only a few of the steel mills of the time believed that the addition of less than one percent RODINE to a sulfuric acid pickling bath could save substantial amounts of acid and metal, while increasing the life of the bath. Today there is no mill chemist who does not know about RODINE and its proven performance in eliminating waste of valuable metal and acid, and its ability to pay for itself through the savings thus gained.

In the past few years much attention has been focused on the use of wetting agents to accelerate pickling. But the fact remains that pickling cycles cannot be reduced by the use of wetting agents alone without severe overpickling problems. Wetting agents do help the acid run off surfaces removed from pickle baths, and, in so doing, reduce carry-over of acid into the rinse.

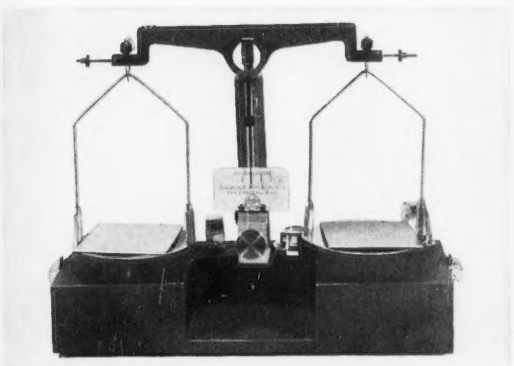
Wetting agents should not be confused with inhibitors to protect the metal and save acid wasted in pitting it. They should not be expected to miraculously speed the removal of scale, even at the expense of wasting the metal. However, the *proper* combination of *real inhibitor* plus correct wetting agent can have beneficial effects on pickling practices.

Only a true inhibitor such as RODINE can offer steel producers solid advantages in pickling. Baths can be operated longer and less acid is required to keep them at desired concentration. Costs of charging and cleaning the bath are reduced, less handling and storing of acid is required. A RODINE bath produces far fewer rejects—steel emerges with uniformly smooth, bright clean surfaces, free of pits, blisters and smut.

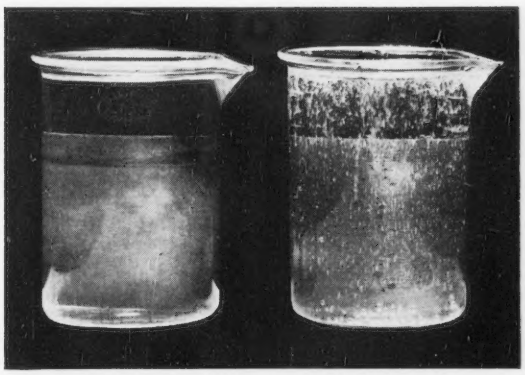
When an Amchem Technical Representative enters your pickle house, you can be assured of experienced assistance in improving your pickling. He will recommend the proper RODINE to 1) prevent needless consumption of acid after scale removal, 2) prevent smutting, pitting and overpickling, 3) produce a stable, free-rinsing foam blanket, 4) improve rinsability and reduce carry-over, and 5) produce a brighter, cleaner surface. Only the Amchem Representative can do this for you because he has at his command the most widely diversified and accepted line of real inhibitors and correct wetting agents available.

Since the early days of pickling acid inhibitor development, scientists in the Amchem Metal Protection Laboratories have constantly studied methods to make the RODINES stronger, more effective and more economical to use. The RODINES of today, as of 40 years ago, are in a class by themselves, have developed a reputation as *the international standard* in acid pickling inhibitors. The fruit of these years of laboratory research and experience in a highly specialized field, and the assistance of Amchem's trained field representatives—specialists in acid pickling techniques—are at your disposal for the asking.

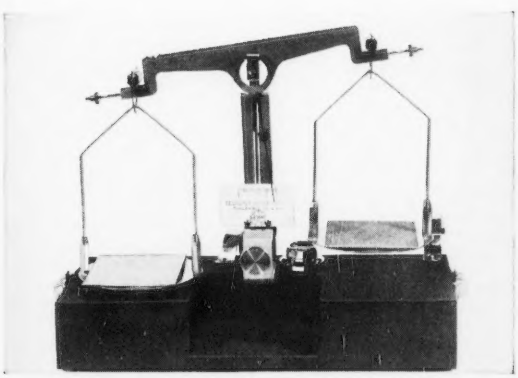
How Rodine Retards Acid's Attack on Metal



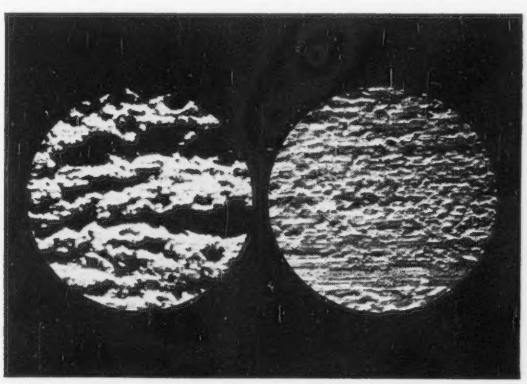
The photographs and microphotographs displayed on this page represent a graphic description of results demonstrating the effectiveness of RODINE in retarding the attack of acid on the metal. NO WEIGHT DIFFERENCE—two identical panels of low-carbon steel are shown being weighed here. They balanced the scale.



RODINE MINIMIZES ACID ATTACK—Each descaled panel was placed in a beaker containing 10% by volume of 66° Bé sulfuric acid of 160° F. The acid in the right-hand beaker was uninhibited. Acid in left-hand beaker was inhibited with RODINE 82, ¼% by volume of the concentrated acid. There was little or no hydrogen evolution in this beaker . . . RODINE retarded the attack of the acid on the base metal.



RODINE SAVES METAL—Both descaled panels were removed from the acid pickle solutions after 5 minutes. The one pickled in the uninhibited acid had lost 1.4% of its original weight. The one pickled in the RODINE-inhibited acid had lost only 0.001% of its original weight. This represents a saving of 26 lb. of steel for each ton pickled; and a simultaneous saving of nearly 50 lbs. of 66° Bé sulfuric acid when RODINE is used to inhibit the acid.



EFFECT OF UNINHIBITED ACID ON THE PANEL — This microphotograph of the low-carbon sheet steel pickled in the uninhibited acid shows deep pits and the crystalline character of the surface after 5 minutes in the solution.

EFFECT OF RODINE-INHIBITED ACID ON THE PANEL — This panel was pickled for 5 minutes in the RODINE-inhibited acid, then microphotographed. Only scale pockets and roll marks are visible; no pitting of the low-carbon sheet steel occurred.

AMCHEM RODINE

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North Central Region Conference in Milwaukee

About 150 Register For Region's Fifth Annual Conference

Total registration was approximately 150 for the October 19-20 Fifth Annual North Central Region Conference held at the Pfister Hotel, Milwaukee, Wis.

Included in the four technical symposia for the conference was the Brewing Industry Symposium, probably the first such session held exclusively on that industry. Four papers were presented "Effects of Metal Ions in the Food and Beverage Industry," by Frank Fink and John Litchfield of Battelle Memorial Institute, Columbus, Ohio, "Paints and Coatings in the Brewing Industry," by Kenneth Tator of Corapolis, Pa., "Cathodic Protection in the Brewing Industry" by E. W. Dreyman, presented by C. W. Ambler, Jr., of American Zinc, Lead & Smelting Co., East St. Louis, Ill., and "Galvanic Corrosion in Steel Brewery Tanks," by Dewey Riggs of Olympia Brewing Co., Olympia, Wash.

Other symposia were on the process, utilities, and pulp and paper industries.

Presented at the conference luncheon and business meeting were new region officers: Chairman C. W. Ambler, Jr., Vice Chairman L. W. Gleekman of Wyandotte Chemicals Corp., Wyandotte, Mich., and Secretary-Treasurer Jack L. Grady of J. L. Grady Co., Kansas City, Mo. (See photograph above.)

The 1962 North Central Region Conference will be held at the Chase Park Plaza Hotel in St. Louis, Mo., October 9-11.

Greater St. Louis Section Plans 3 Meetings for 1961

The Greater St. Louis Section has scheduled its programs for the next three months. For January 12, F. L. Whitney of Monsanto Chemical Company will speak on the subject "Designing to Prevent Corrosion in the Process Industries." This will be a joint meeting with the St. Louis Section of the American Society of Lubricating Engineers.

For the February 13 meeting, J. J. Halbig of Armco Steel will be guest speaker. His subject will be corrosion resistance, properties and uses of 17-4 PH steel.

A. S. Krisher of Monsanto Chemical Company will talk on process industry corrosion for the March 13 meeting.

C. R. Martinson of Monsanto spoke on evaluation of industrial roof coatings for the November 14 meeting.

•

The 1961 North Central Region Conference will be October 9-11, Chase Park Plaza Hotel, St. Louis, Missouri.

MILWAUKEE CONFERENCE SNAPSHOTS-Seated at the head table during the luncheon and business meeting are (left to right in the top photograph) L. W. Gleekman of Wyandotte Chemicals Corp., elected vice chairman of the North Central Region for 1961; C. W. Ambler, Jr., of American Zinc, Lead & Smelting Co., new region chairman; E. F. Moorman of International Harvester Co., region director; A. McConnell, 1960 region chairman and co-chairman of the 1960 regional conference; NACE President-Elect E. C. Greco of United Gas Corp., and Vice President-Elect R. McFarland, Jr., of Hills-McCanna Company. Photograph 1 at the left is a meeting of Technical Committee T-5C-2, Corrosion by Cooling Waters (North Central Region). Photograph 2 shows a carry-over discussion after one symposium. Left to right are Albert Hendricks and John P. Clark of Wisconsin Protective Coatings, Robert J. Swanson of R. J. Swanson Co., and Bob Stiefvater of Associated Sales Company. Photograph 3 shows O. W. Siebert of Monsanto Chemical Company discussing a new type test coupon shape with (left to right) Don Stoltenberg of Carboline Co., E. H. Anderson of Clinton Corn Processing Co., and Don Cushing of Carboline Co. Photograph 4, made at the fellowship hour for regional and section officers, shows Dave Wilson, D. D. Walczyk and A. McConnell, all conference chairmen. Photograph 5 shows Dewey Riggs of Olympic Brewing Co., Olympia, Wash., presenting his paper at the Brewing Industry Symposium. At left is symposium chairman Don Westerman of Miller Brewing Company.

North Central Region

Southwestern Ohio Section heard John R. Schley of Haynes Stellite speak on high temperature corrosion problems of the chemical industry at the October 18 meeting.

•

Cleveland Section had John Lomax of Hercules Powder Co., Wilmington, Del., discuss case histories of Penton linings and coatings in heavy corrosive environments for the November 15 meeting.

Three guest speakers from Heil Process Equipment Corporation talked on structural plastics for corrosive environments in the process industries at the October 18 meeting. Speakers were R. B. King, F. W. Arndt and R. I. Peters.

SECTION CALENDAR

December

6 Ohio Valley Section. Joint meeting with ASM on high temperature corrosion.
7 Teche Section. Petroleum Club.
9 Rocky Mountain Section.
12 Kansas City Section.
12 Greater St. Louis Section.
12 Central Oklahoma Section.
12 North Texas Section. Torch Restaurant, Dallas, 6:30 pm.
13 San Joaquin Valley Section.
13 San Francisco Bay Area Section.
13 Houston Section. Houston Engineers Club.
13 Permian Basin Section.
13 Alamo Section.
13 Twin Cities Section.
15 Vancouver Section. Slide presentation on 1960 NACE Dallas Conference.
20 Cleveland Section.
21 Greater Boston Section. Underground Corrosion of Metallic Structures, by Melvin Romanoff.

January

9 Kansas City Section.
9 Greater St. Louis Section.
9 Central Oklahoma Section.
9 North Texas Section. Torch Restaurant, Dallas, 6:30 pm.
10 San Francisco Bay Area Section.
10 Houston Section.
10 Permian Basin Section.
10 Twin Cities Section.
10 Montreal Section.
17 Cleveland Section.
17 Chicago Section. Engineering Cathodic Protection Systems for Communication Cables, by T. J. Maitland.
19 Vancouver Section.
19 Alamo Section.
23 Tulsa Section.
31 Panhandle Section.
31 Southwestern Ohio Section. Cathodic Protection Panel, Dayton, Ohio.

•

Sale of books in the United States totaled $630 million in 1959.

•

Certificates for presentation to past chairmen of regions and sections are available from the Central Office at $7.50 each.

NALCAMINE® G-39M

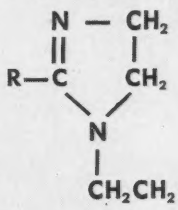
...This low cost fatty diamine makes high quality corrosion inhibitors!

Here's Why!

- It is strongly adsorbed on metallic surfaces . . . Contains *two* cationic centers, making it a really powerful surface active agent.
- It is *readily pourable*, for easiest handling.
- It exhibits excellent stability in corrosive environments.
- It is soluble in hydrocarbons . . . as the free diamine or as its salts of high molecular weight acids.
- It makes normally water-accepting surfaces oil wettable.
- It can be alkylated, oxyalkylated, quaternized or converted to salts of acids by neutralization.

Nalcamine G-39M has been designed expressly for use in products where pharmaceutical purity and color are not required. Thus it offers you all these important properties for a top corrosion inhibitor at a really *down to earth cost!*

THIS IS NALCAMINE® G-39M



Nalcamine G-39M is a mixture of diamino imidazolines, consisting predominantly of the diamine shown above where the mixed alkyl chains are heptadecenyl and heptadecadienyl.

TYPICAL ANALYSIS

Apparent Molecular Wt.	422
Apparent Combining Wt.	211
% Imidazoline	94.0
% Titratables	99.2
Spec. Gravity at 60°F.	0.948
Pour Point °F.	25
Viscosity at 60°F. cps.	334
Density—Lbs. per gallon	7.91
Color	Black

SHIPPING

Nalcamine G-39M is shipped in fifty-four gallon, bung, unlined, non-returnable steel drums. Weight of each drum is approximately 420 lbs.

HANDLING

Nalcamine G-39M can be handled or stored in iron or mild steel. It should be stored in a closed container.

NALCO CHEMICAL COMPANY

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...Serving Industry through Practical Applied Science

Nalco CHEMICALS

Greco, McFarland, Gribble Elected for 1961-62

Edward C. Greco
President

Officers, Directors To Take Office After Buffalo Conference

Edward C. Greco, senior research chemist of the research department at United Gas Corp., Shreveport, La., has been elected president of NACE for 1961-62. Rolland McFarland, Jr., secretary and technical director of the Hills-McKanna Company, Chicago, Ill., was elected vice president and Charles G. Gribble, Jr., district manager for Metal Goods Corp., Houston, Texas was re-elected treasurer.

These officers will take office on the last day of the 17th Annual NACE Conference to be held March 13-17 in Buffalo, N. Y.

Also elected were three directors for three-year terms: L. W. Gleekman of Wyandotte Chemicals Corp., Wyandotte, Mich., and Fred D. Stull of Texas Gas Transmission Corp., Owensboro, Ky., to represent corporate members and Frank E. Kulman of Consolidated Edison Company of New York, Inc., New York City, to represent active members.

Rolland McFarland, Jr.
Vice President

Charles G. Gribble, Jr.
Treasurer

BOARD OF DIRECTORS

Gleekman

Kulman

Stull

President-elect Greco was NACE vice-president for 1960-61. A member of NACE since 1946, he has been chairman and vice chairman of the Technical Practices Committee and chairman of technical committees investigating corrosion in oil and gas well equipment. Three of his technical papers have been published in CORROSION Magazine, and he served as secretary-treasurer of the South Central Region in 1956. He is a graduate of Northwestern Louisiana State College.

His interest and activities in helping improve public education, especially in science, were recognized by a special commendation from the Louisiana State Department of Education. He has been president of the Louisiana Academy of Sciences and state director for the American Association for the Advancement of Sciences. He also has been state director of Science Fairs in Louisiana which he helped organize in 1957. He also has been chairman and councilor of the Ark-La-Tex Section of the American Chemical Society.

He is a Fellow in the American Institute of Chemists and is a member of the Corrosion Research Council of the Engineering Foundation.

Rolland McFarland, Jr., recently elected NACE vice president for 1961-62, has been engaged in design and application of pumps, valves and allied equipment for over 20 years. An NACE member since 1948, he has been chairman of Technical Committee T-6A and currently is an NACE director representing active membership. He also is a member of AIChE, ACS and ASM and is a graduate of Armour Institute of Technology's School of Chemical Engineering.

Charles G. Gribble, Jr., has been re-elected as treasurer of NACE. Active in the Houston Section, he has held most of the offices in that section including 1952 chairman. On the national level, he has been a member of the NACE Board of Directors representing corporate membership, chairman of the local arrangements committee for the 1952 Annual Conference in Galveston and co-chairman for exhibits at the 1957 Annual Conference in St. Louis.

L. W. Gleekman, supervisor of the Materials Engineering Group, Engineering and Development Division of Wyandotte Chemicals Corp., has been a member of NACE since 1954. His NACE activities include chairman of the Detroit Section, membership on several technical committees, chairman of T-5A-4 (1957-58) and technical program chairman for the 1956 North Central Region Conference. He has a PhD in chemical engineering from the State University of Iowa.

Frank E. Kulman is a senior engineer with Consolidated Edison, where he has been employed for 34 years. An NACE member since 1946, he also is a member of AGA, AIEE and NSPE. His work in NACE has included chairman of the Metropolitan New York Section, chairman and membership in several technical committees and currently member of the Editorial Review Committee. He has a masters in electrical engineering from Polytechnical Institute of Brooklyn.

Fred D. Stull, superintendent of corrosion prevention with Texas Gas Trans-

(Continued on Page 48)

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Northeast Region

Plans Well Underway for 1962 Albany Conference

Plans are being made almost two years in advance for the 1962 Northeast Region Conference to be held October 1-3, 1962, at the Hotel Sheraton-Ten Eyck, Albany, N.Y.

Host section will be the Schenectady-Albany-Troy Section. Conference general chairman will be Edward L. Simons of General Electric Research Laboratory, Schenectady, N. Y. Other officers include conference general vice chairman Sherman L. Williams of General Electric, Schenectady, N.Y., and technical program chairman Norbert D. Greene of Rensselaer Polytechnic Institute, Troy, N.Y.

Tentative program for the 1962 conference includes six technical symposia as follows: impressed current protection, corrosion in chemical and paper industries, stress corrosion mechanisms, marine corrosion, recent developments in corrosion and corrosion in energy conversion systems.

Plant trips, fellowship hour and banquet also are being planned.

Schenectady-Albany-Troy Completes '61 Programs

Three programs to complete the 1960-61 section schedule have been planned by the Schenectady-Albany-Troy Section. They are given below and supplement the programs listed on Page 66 of the October issue of CORROSION. L

February 1: "What I'd Like to Know About Corrosion" by D. A. Vermilyea of General Electric Research Laboratory. Corrosion from the viewpoint of details of atomic processes involved.

March 1: "Corrosion Problems Associated With Copper Base Alloys and Means Established to Minimize These Problems" by Wilson Lynes, Revere Copper & Brass, Inc.

April 5: Ladies Night. "Corrosion in the Home" will be the topic by guest speaker E. A. Tice of International Nickel Co., Inc.

•

Pittsburgh Section had the largest attendance in several years for the October 6 meeting. A total of 33 members and 23 guests were counted. Guest speaker Leonard C. Rowe of General Motors Corp., spoke on the subject "Combating Automobile Corrosion Problems Through Design, Special Processing and Materials."

•

Greater Boston Section held a joint meeting with the Boston branch of the American Electroplaters' Society on November 3. Robert LeMoyne of Graco Corp., spoke on airless spray painting.

•

Philadelphia Section heard Charles Barret of the National Aeronautics and space Agency, Cleveland, Ohio, speak on corrosion problems of propulsion systems of space craft at the October 28 meeting.

Next section meeting is scheduled for Tuesday, December 20.

•

Kanawha Valley Section heard John Schley of Haynes Sealight Company speak on corrosion in the chemical industry at the November 17 meeting.

Dates have been set for three meetings: January 21 at Charleston, March 21 at Marietta, Ohio, and May 19 at Charleston.

•

Genesee Valley Section heard John Lomax of Hercules Powder Company talk on Penton, a chlorinated polyethylene polymer, at the October 25 meeting.

•

Southern New England Section held a plant tour as part of its October 19 meeting. The afternoon tour was held at the Charles Pfizer & Company's new Research Center at Groton, Conn. Guest speaker was G. T. Paul.

•

Baltimore-Washington Section officers have begun steps to affiliate with the Maryland Committee of the Engineer's Council for Professional Development. This affiliation is part of the section's education committee work to help promote science education in the public schools.

•

Metropolitan New York Section will have NACE President George E. Best as guest speaker for the December 14 meeting to be held at the Brass Rail Restaurant, 521 Fifth Avenue at 43rd Street. Special guests will include F. L. LaQue, L. B. Donovan, E. A. Noppel and all past section chairmen from 1949 to present.

•

Twin City Section has scheduled Wayne Z. Friend of International Nickel Co., Inc., as guest speaker for the December 13 meeting.

Illinois Short Course Cancelled for 1961

The biennial corrosion short course at the University of Illinois will not be scheduled for 1961. Co-chairmen of the 1959 short course, H. N. Hayward, M. Metzger and Walter H. Bruckner of the University of Illinois faculty, recommended that the short course not be given in 1961 because university staff time and space could not be justified on basis of the low registration for the course in 1957 and 1959.

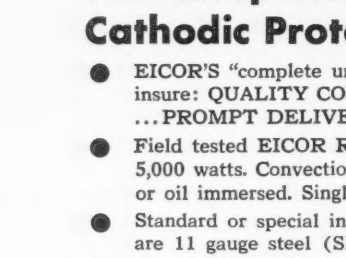
Officers Elected—

(Continued From Page 46)

mission Corp., is a charter corporate member of NACE. His activities in the association have included chairmanship of the Southeast Region. He received his education at Austin College, Rice Institute and Georgia School of Technology. For the past 25 years of his 30 years with Texas Gas Transmission and its predecessor companies, he has specialized in corrosion control work.

•

The Shreveport Section will hold a corrosion short course February 14-15 at Centenary College, Shreveport, La.



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Foreign Corrosion Reports

Corrosion Report for South Africa: 1956-1959

A report on corrosion activities from 1956-59 in South Africa has been received by the Inter-Society Corrosion Committee's Subcommittee on Relations with Foreign Organizations.

The report printed below was submitted by W. J. Copenhagen, Corrosion Unit, South African Council for Scientific and Industrial Research, Liesbeek Road, Roseband, Cape, South Africa.

In the Union of South Africa there is no technical society with a primary interest in corrosion. The subject receives attention from individuals in industrial organizations and from members of the South African Council for Scientific and Industrial Research (CSIR). Papers are published in a number of South African journals from which the following selected list has been prepared for the years 1957-58.

Corrosion Papers Published in 1957-58

D. J. S. Gray. Application of Chemically Resistant Cements and Plastics as Materials of Construction in Chemical Industry. *South African Ind Chem*, **12** 237-244 (1958) December.

L. G. Davis. Causes and Prevention of Corrosion in Machine Shops. *Industrial Review of Africa*, **10**, 5253 (1958) September.

W. J. Copenhagen. Corrosion and Protection of Metals Used in the Building Industry. *National Bldg Research Institute Bulletin*, **16**, 76-82 (1958) March.

D. Proctor-Sims. Corrosion Control. *South Bldg and Timber Trades Journ*, **7**, 19-20 (1957) February.

D. A. Lewis and W. J. Copenhagen. Corrosion of Reinforcing Steel in Concrete in Marine Atmospheres. *South African Ind Chemist*, **10**, 207-219 (1957) October. Also *Corrosion*, **15**, 382t (1957) July.

J. J. Harrison-Smith. Flame Cleaning. *Engineer and Foundryman*, **22**, 68-70 (1958) April.

Interim Recommendations by National Building Research Institute to Reduce Corrosion of Reinforcing Steel in Concrete. *Trans South African Institution of Civil Engineers*, **7**, 248-250 (1957) August.

H. R. Nicholls. Notes on Plastics in Mining With Special Reference to Lining of Water Pipes. *Journ Institution of Certificates Engineers*, **30**, 264-265 (1957) September.

G. M. Hamilton. Painting Structural Steel. *South African Mechanical Engineer*, **7**, 56-69 (1957) October.

G. M. Hamilton. Principles of Protection by Paint. *South African Sugar Journ*, **42**, 969-975 (1958) November.

W. G. Boustred. Production of Corrosion Resisting Steel Castings for the Uranium Industry. *South African Mechanical Engineer*, **6**, 199-211 (1957) January. Author's reply to discussion, Vol. 6, 495 (1957) June.

H. G. Horrell. Range of Ferrous Alloys to Combat Abrasion Corrosion and Heat. *South African Mechanical Engineer*, **8**, 89-116 (1958) November.

L. Pearl. Rapid Laboratory Method for Determination of Soil Corrosiveness on Steel Pipes. *Rhodesian Engineer*, **3**, 45-46 (1958) November.

CSIR Corrosion Activities

Corrosion in buildings is dealt with by D. A. Lewis of the National Building Research Institute, Pretoria.

In Capetown, W. J. Copenhagen heads a corrosion group dealing with varied problems such as metal preparation and painting, inhibitors, metallization, buried cable sheath corrosion, corrosion of naval vessels and aircraft, corrosion in refrigerating plants and behavior of paints and metals in South Africa. Special work has been done on the corrosion of reinforcing steel in concrete structures exposed to marine atmospheres and on the cavitation of manganese bronze propellers.

From time to time lectures on corrosion are given to engineers, architects and chemists. These are a regular feature for final year engineers at the universities.

1960 University Short Course

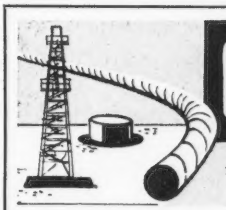
During 1960, a one-week corrosion short course was arranged by Dr. Robinson at the University of Witwatersand.

1960 Corrosion Show Color Slide-Talk

A show consisting of 108 color slides has been prepared showing some of the exhibits at the March 15-17 Dallas exhibition. This 1960 Corrosion Show color slide presentation will be accompanied by a commentary describing the exhibits and many of the items displayed.

NACE Section program chairmen who are interested in using this in one of their programs may make bookings by writing to G. A. Rolak, 1061 M & M Bldg., Houston 2 Texas.

The show gives members who were unable to attend the conference an opportunity to see some of the exhibits at what many have said was the best Corrosion Show held so far.



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Would an experienced corrosion engineer make these mistakes in running current requirement tests for protection of a bare pipe line:

(1) **Use an electrically isolated lateral line as the ground bed?** The answer is, of course, "No." Current distribution along the line—the single most important factor in cathodic protection—is a function of the distance of the ground bed from the pipe line.

The same principle applies to the casing in oil and gas wells, because the casing is simply a vertical pipe line. The current required for external protection cannot be resolved by the Log Current-Potential method if the flow line—insulated off or disconnected at the well head—is used as the ground bed. This fallacy has been demonstrated many times by measuring the current pick-up along the casing with the down-the-hole potential-drop test.

If factual data is to be obtained, a temporary ground bed positioned the same distance out from the well as the permanent ground bed must be used.

(2) **Measure pipe-to-soil potentials with the reference half-cell located on the opposite side of other pipe lines?** Again, the answer is "No." Also, in running Log Current-Potential curves on wells, it is important that the half-cell have an unobstructed view of the well under test.

Your best assurance of obtaining factual information from current requirement surveys on wells is to call CSI engineers. They developed the surface instruments and techniques used to run Log Current-Potential curves which correlate best with down-the-hole potential-drop tests. They have almost a quarter of a century's experience in successful cathodic protection.

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South Central Region Conference Registration Totals About 500

Photograph 1—J. E. Loeffler of Thornhill Craver Co., Houston, at right congratulates H. V. Beezley of United Gas Corp., Shreveport, La., who has been appointed to succeed Mr. Loeffler as chairman of the South Central Region Education Committee. He will assume the chairmanship in January.

•

Photograph 2—Seen at the reception and dinner for South Central Region officers and conference chairmen: (left to right) Conference Chairman W. F. Levert, United Gas Pipe Line Co., Shreveport, La., Technical Program Chairman J. P. Barrett of Pan American Petroleum Corp., Tulsa, South Central Region Vice Chairman Dan H. Carpenter of Atlas Powder Co., Oklahoma City, NACE President George E. Best of Manufacturing Chemists' Association, Washington, D. C., NACE Vice President E. C. Greco of United Gas Corp., Shreveport, La., General Conference Chairman Richard E. Lembcke of Cities Service Research & Development Co., Tulsa, and NACE Executive Secretary T. J. Hull, Houston.

•

Photograph 3—One of informal discussions following a symposium meeting. Left to right are J. E. Landers and Burton Casad of Continental Oil, Ponca City, Okla., Donald B. Anthony of Atlantic Refining Co., Dallas, and Leonard C. Hill of Kansas-Nebraska Natural Gas Co., Inc., Hastings, Neb.

Photograph 4—Sixteen technical committee meetings held at the conference were well attended. Shown here is the meeting of Technical Committee T-6B on Protective Coatings for Resistance to Atmospheric Corrosion.

•

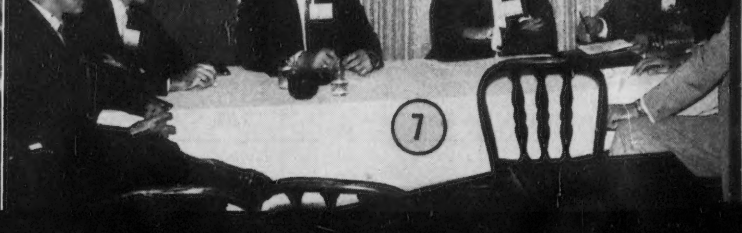
Photograph 5—At the Fellowship Hour, left to right, are D. R. Fincher of Tidewater Oil Co., Houston, Lee R. DeRouen of Union Texas Natural Gas Corp., Lake Charles, La., and Joe Rench of Napko Corp., Houston.

•

Photograph 6—At the Fellowship Hour, center attraction was a magician with considerable skill and finesse at cards and slight-of-hand.

•

Photograph 7—An informal discussion continues after the meeting of Technical Committee T-1H on Economics of Corrosion Control. Shown left to right are Howard Olson of Shell Oil Co., Denver, Colo., Fair Colvin, Jr., of Atlantic Refining Co., Midland, T-1H Chairman R. M. Robinson of Continental Oil Co., Houston, T-1H Vice Chairman E. J. Simmons of Sun Oil Co., Dallas, Harry J. Kipps of Signal Oil & Gas Co., Los Angeles, Cal., and Harry G. Byars of Atlantic Refining Co., Dallas.



South Central Region

Sabine-Neches Section Elects 1961 Officers

New officers elected for 1961 at the November 3 Sabine-Neches Section meeting are as follows: Chairman Ralph P. Gulley of Gulf Oil Corp., Port Arthur; Vice Chairman Hugh S. Hickerson, Jr., of Columbia-Southern Chemical Corp., Lake Charles, La., Secretary-Treasurer Hal Pitman of Southern Union Gas Co., Port Arthur, and Trustee Joe Picarazzi of Cities Service Oil Refining Corp., Lake Charles, La.

The section voted to affiliate with the newly organized Gulf Coast Engineering and Scientific Society and elected Joe Cunningham and C. A. Murray as directors to represent the NACE section.

Paul Pukoris of Nalco Chemical Co., Chicago, Ill., was scheduled for guest speaker at the December 1 meeting. His subject was pretreatment of equipment to reduce water side corrosion.

H. V. Beezley to Head Education Committee

H. V. Beezley, United Gas Company, Shreveport, La. will become chairman of South Central Region's education committee effective January 1. Mr. Beezley succeeds John E. Loeffler, Thornhill-Craver Co., Houston, who has been chairman of the committee for the past several years.

Mr. Beezley was vice-chairman of the committee this year. Mr. Loeffler expects to devote his time to completion of a committee aim to publish a book on the fundamentals of corrosion for distribution among high school students.

Dobie and Gibson Elected Alamo Section Chairmen

New officers were elected by the Alamo Section at its October 18 meeting. These 1961 officers are as follows: Chairman Ray Dobie, Vice Chairman Joe Gibson, Secretary-Treasurer J. W. Gamblin and Trustee Max Schlather.

The section's regular meeting date has been changed to the third Thursday of every month.

Speaker at the October meeting was R. B. Bender of Tejas Plastics Material Supply Co., Fort Worth. His subject was plastics as a tool for industry.

Woody Outlines Program For 1961 Houston Meeting

C. L. Woody, United Gas Corp., Houston general chairman for the South Central Region's October, 1961 conference to be held in Houston, outlined a 4-day program to the region's officers and trustees at Tulsa. His announcement was made during the annual meeting of the trustees held at noon October 25.

Mr. Woody said plans for the Houston meeting, which will have a concurrent exhibition, are well under way and that papers for the technical program are being solicited. All sessions and the exhibition will be held at the Shamrock-Hilton Hotel, October 24-27.

Shreveport Section heard Jay R. James of Cathodic Protection Service, Houston, speak on value of hot spot approach to survey and cathodic protection of bare pipes at the November 1 meeting.

•

Central Oklahoma Section meeting will be December 12 at the Topical Cafeteria, Oklahoma City. Speaker will be Cecil Gibson of Oklahoma Natural Gas Company. His subject will be "How to Improve Your Corrosion Control Program Through Training." The 1961 section officers will be elected at the meeting.

•

Permian Basin Section meeting for October 11 included a talk on corrosion control considerations in waterflood plant design by Joe C. Neal of Gulf Oil Corporation, Midland, Texas.

•

East Texas Section heard H. P. Morrow of Aluminum Company of America speak on aluminum applications in the petroleum industry at the October 25 meeting.

•

North Texas Section meeting for November 14 included a talk on new techniques of inhibition in producing oil and gas wells by D. R. Fincher of Tidewater Oil Co., Houston.

•

The 7th Annual Houston Section Corrosion Control Short Course will be held February 2-3 at the Rice Hotel, Houston.

•

News deadline for CORROSION is the 10th of each month.

Improved Application Techniques Discussed

NACE Technical Unit Committee 6D, at its meeting October 25 at Tulsa during the South Central Region Conference, considered methods by which improvements in application technique can be taught. There have been marked advances in materials, equipment and understanding of fundamental problems associated with paint and its application during the last several years, the discussion revealed. It was also considered true that these advantages frequently are of no significance because workmen do not know how to use new equipment or to apply new materials properly.

The committee is concerned with industrial maintenance painting problems.

Committee T-1F to Make Wellhead Parts List

Committeemen of T-1F decided at their Tulsa Conference meeting to compile a list of parts used in wellheads with a description of materials and trade names. The committee is interested especially in materials designed to resist corrosion from high pressure sour condensate wells.

Aim of the study is to single out the materials best suited for wellheads, especially on highly corrosive wells.

•

The Shreveport Section will hold a corrosion short course February 14-15 at Centenary College, Shreveport, La.

•

The 1961 South Central Region Conference and Exhibition will be October 24-27, Shamrock-Hilton Hotel, Houston, Texas.

Proceedings

SHORT COURSE

on

PROCESS INDUSTRY CORROSION

Twenty papers presented Sept. 12-16 at the symposium sponsored jointly by Ohio State University and NACE Technical Group Committee T-5 on Corrosion Problems in the Process Industries. The 450-page book measures 8½ x 11 inches, has a plastic back, flat opening. Many tables, graphs and illustrations; hundreds of references.

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These papers are by engineers concerned with controlling corrosion in some of the nation's largest chemical processing plants. Considered are use of metal and plastic materials in a wide variety of environments, including most of the common acids and alkalis; special problems found in both low and high temperature processes, corrosion measurements, coatings, design and other practical information.

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Letters to the Editor

Cheshire, England
21 October, 1960

To the Editor of CORROSION:

Economics is about choice. In a world of absolute plenty there would be no economic problems and resources could be used with the utmost extravagance. Corrosion uses up a lot of resources and therefore, even I take it in America, where resources are scarce relative to the ends to which they might be applied, it creates or helps to create economic problems.

Whose and what are these problems? They are the problems of the national economy and the firm's economy, but to both essentially they are the same problem. How much of a problem is corrosion? It usually is expressed insofar as possible in terms of cold cash, but inevitably there are intangibles—unknowns which may on occasion turn out to be more important than known factors. Once a decision is reached to attempt to answer this question, one may begin to tackle the problem of how much can be spent justifiable to avoid corrosion.

Dealing with the macro or nation-wide economic aspects of corrosion, I must first make clear that I have never had the privilege and pleasure of visiting your country. Therefore in almost everything I say about it, I speak from deep ignorance. Nevertheless, I have the feeling that marco-economically speaking corrosion does not really matter in your country, Dr. Uhlig's $6 billion notwithstanding. In other words your economy can create capital (and other) goods at such a fantastic rate, that the absence of corrosion would aggravate what is in any case a fairly embarrassing problem. However this is not really an argument for letting corrosion rip, because there are without doubt pleasanter and more useful ways of balancing the productive and consumptive capacities of the United States.

I have deliberately drawn this perhaps somewhat exaggerated picture in order to highlight the difference with the macro-economic position in my own country. Here we do not have resources to spare. We have an economic problem fundamental to the future of the British people, namely that of maintaining and improving the efficiency of British Industry, our principal bread-winner. To do this I believe we need to develop an economic strategy.

Gone are the days when Britian could be first and best in everything! Today we must try and solve the problem of determining in which sectors of the economy our scarce resources should be concentrated, in order that the greatest long term return be gained. In modern terms, this problem largely resolves itself into the disposal of what is in Britain, the scarcest of all resources, namely scientific and technological effort and "know how". We have in this country what I call the "at all costs" school of thought, "at all costs" we must have atomic energy power stations, hydrogen power development, nuclear marine propulsion, supersonic airliners, space research of course, and so on. Very few of those who propose these measures, seem to measure their cost, not just in terms of mere money, but of scarce scientific and technological effort, or indeed measure the "pay back" on this effort. It is my strong impression that the group of scientists best trained as salesmen, is able to gain the lion's share of the scarce resources going.

We have, for example, since the war gone in for an enormously expensive nuclear power programe, to give us power 30 to 40 percent more expensive than that obtained from conventionally-powered stations. These are the latest figures, and the break-even date for the two costs has been successively postponed from 1965 to 1970 and now to 1975. How much more this is now going to cost us or how cheap we might have made conventional power with the same expenditure of effort nobody has mentioned or seems to have considered. However, we may be certain that it will be particularly expensive in terms of that scarcest of all resources: Scientists and technologists.

The point I am reaching by this rather lengthy route, is not of course that Britian should not enter the scientific and technological race, even in these fields where the "pay back" may be lengthy. Rather, we should think carefully about which events in this race we should enter. We should, however, be careful not to forego certain events because they lack the glamor of nuclear power or space research, but should, instead, favor these events which often give a much more certain, nearer in time, though *possible* smaller return. Corrosion prevention seems to me to come into this category. Dr. Uhlig's $6 billion per annum may not be significant in the context of the U. S. economy but Dr. Vernon's comparable 400 million pounds sterling per annum of direct corrosion losses in the United Kingdom certainly is. Inexact though it is (as Dr. Vernon himself is the first to admit, indeed to emphasize) it is a measure of the return a greater investment in corrosion prevention would bring.

Dr. Vernon's figure is likely to be an underestimate because while it is comparatively easy to measure the effect of a more plentiful and cheaper energy supply, we have hardly begun to measure what it costs to do as little as we do do, and know as little as we do know about corrosion. One example comes to my mind as I am currently working in the petrochemical industry. Here we have the outstanding "growth" industry of the mid-twentieth century, responsible for a very substantial amount of fixed investment. In the plant of this industry, even normally corrodible materials often are subject to operating conditions of pressure and temperature obviously previously unknown. How much corrosion knowledge has been gained here ex post instead of ex ante? What resources of men and materials could have been saved had more been invested in gaining this knowledge ex ante? An investigation of such a problem would, I suggest, reveal to some national economic strategist that the return on such an investment would compare favorably in rate and certainty with others we have little or no hesitation in embarking upon.

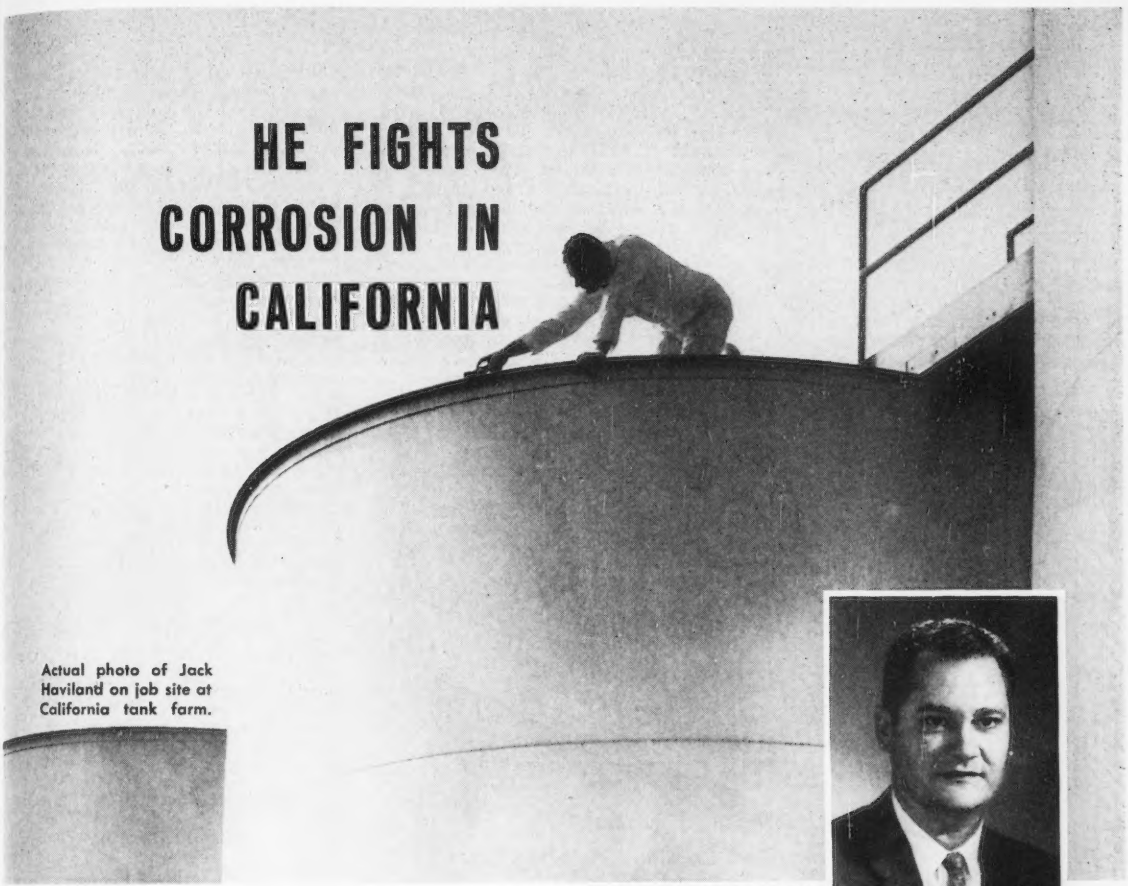
In Britain we have a problem, like one which has recently begun to irritate the United States is so serious it literally determines the level of our standard of living. I refer of course to our Balance of Payments or more precisely our Balance of Trade. Corrosion inevitably must exert an unfavorable effect on this balance. Britain is a gigantic workshop taking in raw materials at one end and sending out the finished manufactured goods at the other end. The profit on such a business, with given factor and final product prices is dependent the rate of transformation of imports to exports. Corrosion deleteriously affects this rate in particular by raising the "import content" of our exports. Furthermore it raises Britain's own "cost of living," i.e. the volume of imports retained must be greater to offset losses from corrosion. Corrosion control is particularly important because of Britain's traditional trade with countries having warmer climates, in which exports may and indeed sometimes do arrive in a corroded form with disadvantageous effects on our trade. Finally, the assumption of constant factor prices does not apply. Rising real costs of world metals and minerals, (of which more later) produce rising import prices; therefore, Britain's "terms of trade" become less advantageous with consequent deleterious effects on her Balance of Payments.

There is I think, another international aspect which will affect both the U.S. and the U.K. economically. More metals, and particularly ferrous metal, have come into use in the last 150 years than in all previous history of man. The revolution in the modes and methods of production, which can hardly be said to have stabilized in the countries in which it began, is now seriously beginning to affect those areas of the world in which by far the greatest part of the world's population is concentrated. Without in any way subscribing to Malthusian prophecies of doom, it seems most likely, therefore, that the rate of consumption of the world's resources of ores and metals is likely to grow considerably, if not exponentially. If this is true, then despite the powerful counteracting force of science and technology, it is clear that we must seek metals and ores of increasingly lower yields in increasingly inaccessible plans at increasingly higher costs.

A considerable mass of evidence exists to support the case I have just made, indeed this same case was one of the main themes of the President's Materials Policy Commission in 1952, the so called Paley Commission. A few figures will help to emphasize the point. Of the total world production of 6,500 million long tons of crude steel ever recorded up to 1957, 3,600 million long tons, or rather more than half were produced in the last 20 years. How powerful in the effect of compound interest at about 3% in this case! If we are to continue compounding at something like this rate, namely that of 1957 or 1956, not surely an unreasonably assumption, until 1977, then the following significant result emerges. Over the

(Continued on Page 54)

HE FIGHTS CORROSION IN CALIFORNIA



Actual photo of Jack Haviland on job site at California tank farm.

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Letters to the Editor

(Continued From Page 52)

20-year period 1957-77 the world will use 8,300 million tons of crude steel which is approximately one and one-third times the total production ever recorded up to 1957. Despite the powerful counteracting force of more advanced technology, the Law of Diminishing Returns will, for the reasons outlined, inexorably exert its effect to the end that real costs of obtaining the world's metals is bound to rise. Increased world population and the increased industrialization of life of an increasing part of this population; the rise in land values that these two factors cause; higher costs of labor; all these are probably the most important supporting reasons for this hypothesis.

The logic of this argument is that, while we may reject the more extreme aspects of Malthusianism, we must accept that in itself the phenomenon just described is bound to significantly retard industrial development and limit rising standards and living. The Paley Commission drew attention to this. Consequently, it will be generally agreed, that more effective corrosion prevention can make a very important, if not the single most important contribution of all to the conservation of resources.

More must be done about controlling corrosion at the level of the firm. What forces influence a firm investing in corrosion prevention? They are of the same kind that affect investment decisions in all capitalistic economies. Taxation does not help. A good "pay back" takes on a less rosy hue and a bad one looks worse. In other words, net savings are rather less than the gross (in the U.K. about half). Modern governments cannot avoid taxation but greater attention needs to be given to ensuring that taxation causes minimum disturbance to the economy, and in particular does not inhibit decisions to put aside more for investment.

Decisions on investing in "scientific capital" are hampered by lack of knowledge and general uncertainty. Corrosion prevention clearly falls into this category. Even if the expertise is present there is a fundamental difficulty of giving quantitative predictions of service life from the results of corrosion tests. This lack of precise predictions must have a powerful effect in corrosion work, because the cost of improved measures usually has to be met at the outset and the benefits are normally spread over the whole life of the asset. Much more general, though is the case of the lack of expertise. Those concerned are not scientifically "literate." They are "illiterate" as to the causes and effects of corrosion and certainly as to its costs and therefore as to the savings likely to accrue from additional corrosion prevention. This is why only limited benefits accrue from the efforts of such bodies as the Corrosion Group of the S.C.I. and the Corrosion Laboratory of the Department of Scientific and Industrial Research in this country and of NACE in the U.S. In other words, a lack of trained technologists in this or in any other field must mean a break in the circuit of communication, and a consequent failure to communicate ideas and fresh developments in corrosion prevention to those concerned with investment decisions.

I am acutely aware that my observations have been general in character. Too general, for it would obviously have been far more valuable to back what are after all just a batch of hypotheses with some hard facts and figures. I hold strongly to the view that those directly concerned with research into the field of corrosion, and dissemination of corrosion knowledge, in particular NACE in your country and the Corrosion Group of the S.C.I. in my own, need to very assiduously concern themselves with the gathering of such facts and figures. They should, that is, concentrate more of their activities on economic research, which at this stage is just as important as scientific. It is through the knowledge gained from the former that, I believe, the more progress may be made in spreading the existing scientific knowledge to the greatest effect, and stimulating further investigation into the problem of mitigating the effects of corrosion.

A. KEYNES

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CORROSION ABSTRACTS

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1. GENERAL

1.6 Books

1.6, 3.5.8

Physical Metallurgy of Stress Corrosion Fracture. Thor N. Rhodin, Editor. Book, 1959, 394 pp. Interscience Publishers, Inc., 250 5th Ave., New York 1, N. Y. and Interscience Publishers, Ltd., 88-90 Chancery Lane, London, W.C.2.

Volume of a series of volumes published by the Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers. The book consists of papers presented at a symposium at Pittsburgh April 2-3, 1959 with several organizations cooperating, including the National Association of Corrosion Engineers.

Contents include: New Perspective on the Stress Corrosion Problem, by Herbert H. Uhlig; Effect of Electric Strain on the Electrode Potential of Metals by Ling Yang, G. T. Horne and G. M. Pound; Surface Structure and Chemical Interaction, Gert Ehrlich and D. Turnbull; Crack Propagation During Stress Corrosion, C. Edeleanu; Initiation and Propagation of Cracks in the Stress Corrosion of Alpha Brass and Similar Alloys, J. G. Hines and A. J. Forty; Role of Corrosion Products in Crack Propagation in Austenitic Stainless Steel. Electron Microscope Studies, N. A. Nielsen; Effect of Stress and Environment on the Microtopology of the Corrosion Product, E. A. Gulbransen; Stress Corrosion of Single Crystals of Stainless Steel, H. W. Paxton, R. E. Reed, R. D. Leggett; Metallographic and Crystallographic Examination of Stress Corrosion Cracks in Austenitic Cr-Ni Steels, J. G. Hines and R. W. Hugill; Stress Corrosion Cracking of Austenitic Stainless Steels in High Temperature Chloride Waters, W. W. Kirk, F. H. Beck and M. G. Fontana; Effect of Composition on Stress Corrosion Cracking of Some Alloys Containing Nickel, H. R. Copson; Dependence of Stress Corrosion Cracking Susceptibility on Age Hardening in a Copper-Nickel-Silicon Alloy, W. D. Robertson, E. G. Grenier, W. H. Davenport, V. F. Nole; Stress Corrosion Cracking in Low Carbon Steel, Hugh L. Logan; Phenomenon of Cracking and Fracture of Steel in the Presence of Hydrogen. Corrosion Under Stress in the Presence of Moist Hydrogen Sulfide, Paul G. Bastien; Electrochemical Mechanism of Stress Corrosion Cracking of Mild Steel, H. J. Engell and A. Baumel; Current Problems for Additional Consideration, L. R. Scharfstein. 19440

1.6, 3.2.3

Structure and Properties of Thin Films. C. A. Neugebauer, J. B. Newkirk and D. A. Vermilyea, Editors. Book, Dec. 18, 1959, 561 pp. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y.

Proceedings of an international conference held at Bolton Landing, N. Y., September 9-11, 1959, sponsored by the Air Force Office of Scientific Research, Air Research and Development Command and General Electric Research Laboratory, Schenectady.

The 41 papers are arranged under the following topical headings: Formation of thin films, mechanical properties, electrical properties, magnetic properties,

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ATS—Associated Technical Service Abstracts, Associated Technical Services, P. O. Box 271, East Orange, New Jersey.

AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., Inc., 2 Park Ave., New York 16, New York.

BL—Current Technical Literature, Bell Telephone Laboratories, 463 West St., New York 14, New York.

BTR—Battellee Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

CO—Centre d'Information du Cobalt, 35 Rue des Colonies, Brussels 1, Belgium.

EL—Electroplating and Metal Finishing, 85 Udney Park Road, Teddington, Middlesex, England.

GRR—U. S. Government Research Reports, Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

HB—Translations, Henry Brutcher, P. O. Box 157, Altadena, California.

IIM—Transactions of The Indian Institute of Metals, 31 Chowringhee Rd., Calcutta 16, India.

INCO—The International Nickel Co., Inc., 67 Wall Street, New York 5, New York.

JSPS—Japan Society for the Promotion of Science, Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1 Chome Nakameguro, Meguro-Ku, Tokyo, Japan.

LD—Larissa Domnikov, 8101 Creighton Ave., Los Angeles 45, Cal.

LMB—Light Metals Bulletin, Intelligence Dept., British Aluminium Co., Ltd., Norfolk House, St. James' Square, London, SW 1, England.

MA—Metallurgical Abstracts, Institute of Metals, 17 Belgrave Square, London SW 1, England.

NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tennessee.

OTS—Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

PDA—Prevention of Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

Pi—Pergamon Institute, 1404 New York Ave., N. W., Washington 5, D. C.; Oxford and London, England.

PMR—Platinum Metals Review, Johnson, Matthey and Co., Ltd., 73-83 Hatton Garden, London, E.C. 1, England.

RIM—International Union of Testing and Research Laboratories for Materials and Structures, RILEM Bulletin, 12, Rue Brancion, Paris XV, France.

RML—Review of Metal Literature, American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Assoc. of British Paint, Colour and Varnish Manufacturers, Paint Research Station, Waldegrave Rd., Teddington, Middlesex, England.

SE—Stahl und Eisen, Verlag Stahleisen, m.b.H., Breite Strasse 27 (Schliessfach 2590), Dusseldorf, Germany.

TIME—Transactions of The Institute of Marine Engineers, The Memorial Bldg., 76 Mark Lane, London EC 3, England.

TT—Technical Translations, Office of Technical Services, U. S. Department of Commerce, Washington 25, D.C.

ZDA—ZDA Abstracts, Zinc Development Association, 34 Berkeley Square, London W 1, England.

chemical interactions at surfaces, theory of surfaces, a panel discussion. Discussions about each paper are included as recorded.

Examples of the research underway by participants in the conference are given in the papers. These include studies of phase transformation, chemical reactivity, superconductivity, electrical resistance, Hall effect, magnetic properties and magnetoresistance. Also properties of films not exhibited in bulk form. Other papers are concerned with direct observation of defects, structure studies, measurements of specific surface area and observations of the state of stress. Several papers deal with surface chemistry.

A few papers on theory cover epitaxial relationships, the manner in which stresses are introduced and interactions of atoms and surfaces.

Photolithographed in large size typescript, the book is abundantly illustrated and has a subject and author index. 19318

1.7 Organized Studies of Corrosion

1.7.1

Report of Advisory Committee on Corrosion. K. G. Compton. Proc. Am. Soc. Testing Materials, **58,** 229-238 (1958).

Report covers changes in personnel of advisory committee; status of atmospheric test programs (Committees A-5 on Corrosion of Iron and Steel, A-7 on Malleable Iron Castings, A-10 on Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys, B-3 on Corrosion of Non-Ferrous Metals and Alloys, B-7 on Light Metals and Alloys, B-8 on Electrodeposited Metallic Coatings, and C-19 on Structural Sandwich Construction); status of corrosion test methods (Committee D-10 on Shipping Containers and D-15 on Engine Antifreezes); status of ASTM test site program with information on the 12 sites available for general use by ASTM committee (State College, Pan., Columbus, East Chicago, Pittsburgh, Bell Telephone Labs. in New York, Port Authority Bldg. in New York, Newark, Point Reyes, Calif., Kure Beach 80′ and 800′ Lots and Freeport, Texas). Map shows test sites. 41 references.—INCO. 19703

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166a

1.7.1, 5.4.5, 5.3.2

Corrosion. British Iron & Steel Research Association. Annual Report, 1958. (Published 1959), 62-64.

The work carried out by the Corrosion Section is described. A new series of tests on priming paints for sprayed zinc and sprayed aluminum coatings on steel has been started. Several long-term investigations on metal coatings and priming paints for bare steel fully exposed in the open air are still in progress. Preliminary tests on the inhibition of corrosion by sodium silicate have been completed. Twenty different formulations for use as organic finishes of limited protective value for laboratory control tests of phosphate coatings have been tried.—RPI. 19729

2. TESTING

2.3 Laboratory Methods and Tests

2.3.5, 3.6.4, 6.3.21

Contact-Potential Measurements on Cleaned Germanium Surfaces. Alan B. Fowler. J. Applied Physics, **30,** No. 4, 556-558 (1959).

Fowler describes the use of a Kelvin bridge technique to measure the contact potential of the (110) face of the n and p regions of an n-p Ge crystal in a vacuum better than 10^{-9}mm Hg. The doped n and p regions had resistivities of 0.058 and 0.33 Ω cm, respectively. In the absence of surface states the difference in work-function (ϕ) is 0.34 eV, the A-cleaned surface exhibited a difference of 0.002 ($\pm$0.004) eV. The variation of the difference in ϕ with 0 exposure was 0.4 x 10^{-7}mm.min-0.013eV, 28 x 10^{-7}mm.min-0.018eV, and 56 x 10^{-7}mm.min-0.000 ($\pm$ 0.005)eV. These results are discussed in terms of several surface-state distributions. 10 references.—MA. 19736

2.3.2

Sulfur Dioxide Acceleratead Corrosion Test-Testing Conditions and Equipment. J. Edwards. Paper before Am. Electroplater's Soc., Golden Jubilee Conv., Detroit, June 15-19, 1959. Tech. Proc. Am. Electroplater's Soc., **46,** 154-158 (1959).

Effect of varying the temperature of the test atmosphere. Results indicate that the cabinet in which sulfur dioxide accelerated corrosion tests are made should be thermostatically controlled. Scope and applications of this form of accelerated corrosion test.—RML. 19734

2.3.4, 5.3.2

The Ferroxyl Test. (In German.) A. Kutzelnigg. Werkstoffe u. Korrosion, **11,** No. 3, 162-171 (1960) March.

All solutions containing potassium ferricyanide and sodium chloride cause pit corrosion on nickel coatings. With constant sodium chloride content, the corrosion attack is the stronger the higher the ferricyanide content, and the higher the temperature of the solution.

With thin nickel coatings, the ferroxyl test provides so many blue spots that there is no longer any point in counting them. From 12η nickel onwards, mustard yellow spots are encountered which must be interpreted as products of the ferricyanide/nickel reaction. If exposed to the solution for a longer period, these spots become blue.

The ferroxyl test is thus not suited for determining the porosity of nickel coatings. Its usefulness as a corrosion test is impaired by the fact that the test is difficult to reproduce. Even if the test conditions are laid down in great detail, the results obtained by different observers vary greatly. 19251

2.3.6, 6.3.11

Investigation of Surface Changes of a Platinum Electrode by Means of the Electron Microscope. (In German.) H. Grubitsch and K. Heckel. Werkstoffe u. Korrosion, **11,** No. 5, 271-273 (1960) May.

The surface changes of a polished platinum electrode are investigated by means of the electron microscope. This platinum electrode was used as a cathode in a galvanic cell — Cd/O. 1 N NaCl/O, 1 N NaCl, air /P +. The current of the cell was periodically interrupted and closed at intervals of 15 min. each. This gave rise to changes on the platinum surface which could be observed with the aid of the electron microscope. These changes apparently correspond to a reconstruction of the surface, and hence to a lessening of its activity. This reduction in surface activity explains the slow current decrease with ventilating elements the cathode of which dips into an electrolyte with constant oxygen content. 19775

2.3.5, 3.6.4, 3.8.4

Using Contact Resistance to Measure Adsorption of Gases on Metals (and Contact Potentials). P. Kisliuk. Bell System Tech. J., **37,** No. 4, 925-949 (1958).

Contact resistances of molybdenum and tungsten electrodes were used to measure the adsorption of nitrogen and oxygen. A theory relating the resistance of an adsorped film (< 20 A thick) to the thickness is given. Electrons are assumed to flow by quantum-mechanical penetration of a potential barrier caused by a gas layer separating the contacts. Systematic records of contact potentials measured under different experimental conditions are tabulated in an Appendix. 34 references.—MA. 19255

2.3.7, 2.3.5, 5.9.4

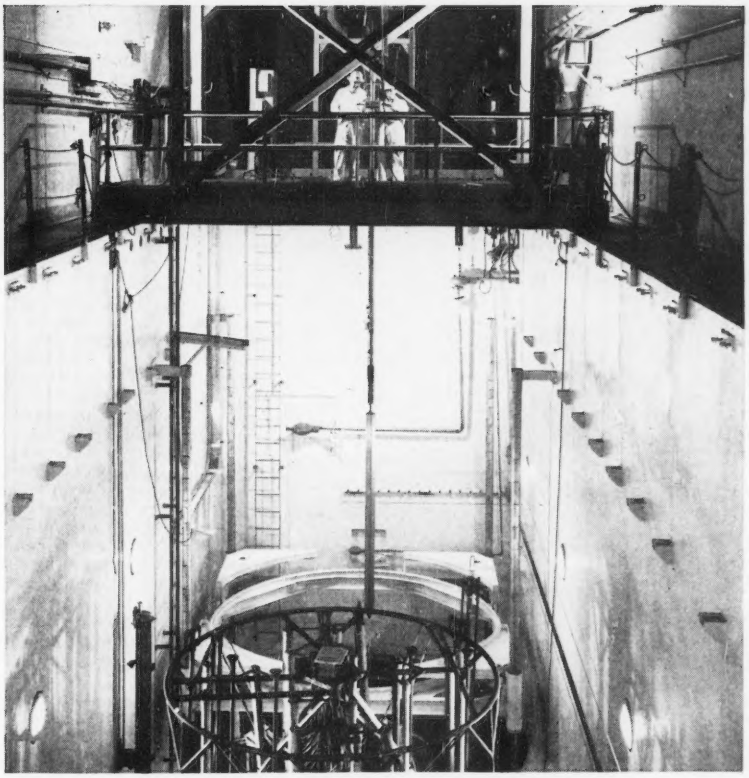
Testing Anodic Coatings. A. W. Brace and K. Pocock. Light Metals, **21,** No. 242, 154-155 (1958).

A review of methods of testing, including breakdown voltage and the effect of film thickness on the electrical impedance. The importance of efficient sealing of the coating is stressed, and methods of carrying out corrosion and abrasive tests are described.—MA. 19728

2.3.7, 3.5.9, 2.4.2

A Method of Specimen Corrosion Protection for High-Temperature Creep Testing. J. R. Bohm, R. E. Uhrig and Glenn Murphy. Ames Lab. U. S. Atomic Energy Commission Pubn., IS-48, October, 1959, 17 pp. Available from Office of Technical Services, Washington, D. C.

The method involves encasing the creep specimen in a flexible capsule which is capable of withstanding exposure to the atmosphere for extended periods at up to 1000 C. The capsule consists of several sections of bellows welded to machined parts which comprise the gage point mounting rings and specimen end-adapters. Provisions are made to attach extensometer linkages through the capsule walls to the speci-



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men gage points. A compound system is used to render the desired coupling.—NSA. 19655

2.3.7, 5.9.4

A Test for the Degree of Sealing of Anodic Coatings on Aluminium. D. E. Bury and H. P. Godard. Electroplating, **12**, No. 6, 219-220 (1959).

Material judged satisfactory, either by use or having been processed within specified limits, is sealed anodically and the weight gain measured. Since a given anodic film has a limiting weight-gain for complete sealing, the weight increase is taken as a measure of the degree of sealing. The test is rapid and simple, but has limited correlation with salt-spray tests. A maximum resealing weight gain of 2 per cent is set as the acceptance limit.—MA. 19653

2.4 Instrumentation

2.4.2

Continuous-Reading Balance for Oxidation Studies. E. Dempsey. J. Sci. Instruments, **36**, No. 2, 84-87 (1959).

An oxidation balance is described which is particularly suited for the study of radioactive and toxic materials. The mode of suspension, although extremely robust, permits the detection of mass changes of 50-100 γ in a sample of mass 1-2g. The instrument shows exceptional constancy of the zero reading even after comparatively rough treatment.—MA. 19768

2.4.2

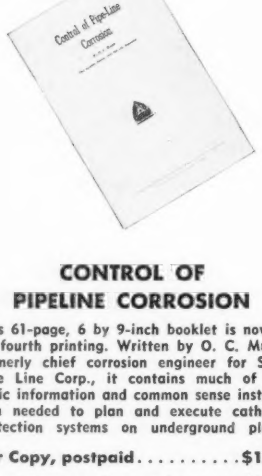
Recording Device for Corrosion Studies. (In Russian.) M. M. Salamzade. Izvest. Vysshikh Ucheb. Zavednii Neft i Gaz (Bull. Inst. Higher Education, Petroleum and Gaz), **2**, No. 7, 117-119 (1959).

In establishing a system for electrical protection of underground installations (e.g. pipelines) against corrosion, a device for continuous measurement and recording of potentials and currents makes it possible simultaneously to measure the potential of the installation with respect to the ground, the drop in voltage along the installation, and the density of leakage current. In addition, large drainage currents may be measured by use of an external shunt, which can be connected to the terminals of the device. The latter consists of a recording millivoltmeter with high internal resistance and with automatic alternate commutation of three circuits. 19495

2.4.3, 2.3.9

Ultrasonic Testing of Products of the Iron and Steel Industry. (In German.) Hermann-Josef Kopineck, H. Krächter and W. Rauterkus. Stahl und Eisen, **79**, No. 11, 786-797 (1959) May 28.

Necessity of using non-destructive tests. The essential features of ultrasonic testing. Peculiarities of their application to the practice. Possibilities of an objective representation and assessment of the results indicated. Characteristic features and fields of application of the testing methods to be considered up to present for the current testing in operation. Examples for their application to forged pieces, heavy plates, sheets as well as seamless and welded tubes. Limitations and difficulties encountered in the interpretation of the ultrasonic test results. Conclusions.—SE. 18396



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2.5 Specifications and Standardization

2.5, 2.3.2

Results of Co-operative Investigations in Several Laboratories for the Development of Standardizable Corrosion-Testing Methods. Pts. I, II, III. W. Wiederholt. Metalloberfläche, **12**, Nos. 10, 11, 12, 305-307, 337-347, 369-371 (1958) October, November, December.

Pt. I. Disagreement in results obtained by different workers in different laboratories from corrosion tests carried out according to five German standard specifications, covering salt-spray and various types of humid-atmosphere conditions led to an examination of the apparatus and conditions employed, in order to provide, if possible, more precise specifications that will give reproducible results. Details are given of the apparatus and conditions used in 15 German industrial and government laboratories.

Pt. II. The results of tests carried out in the various laboratories on bright-chromium-plated zinc die-cast threaded components, and commercial zinc and steel sheet are described and are analyzed in detail.

Pt. III. Illustrated descriptions are given of the design, construction and operation of recommended standard types of cabinets for salt-spray, humidity, and alternating-immersion tests; their use would enable concordant results to be obtained.—MA. 18987

2.5, 2.3.9

Electromagnetic Testing of Tubing: Standardization of Specifications and Test Methods. Pt. I. Richard Hochschild. Non-Destructive Testing, **16**, No. 6, 495-499 (1958).

Standardization of eddy-current testing is discussed with special reference to the suppression of the undesired response to dimensional and physical variables which interferes with defect detection. Recommendations are made for the design of reference specimens (consisting of pipes with holes drilled in the walls) which can be made by any testing laboratory for testing equipment and for inter-laboratory correlation.—MA. 18166

2.5, 6.3.6, 1.6

ASTM Standards on Copper and Copper Alloys. Book, December, 1959, 704 pp., 6 x 9 inches, cloth. Available from: American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.

A compilation of ASTM standards, specifications and test methods on copper and copper alloys, cast and wrought copper and copper-alloy electrical conductors, non-ferrous metals used in copper alloys. The book is sponsored by ASTM Committee B-5.

The book contains hundreds of specifications, methods and definitions. There are appendices concerning classification of wrought copper-base alloys, regulations governing committee B-5, personnel of the committee and representatives of the committee on other committees. There is an alphabetical subject index. 19603

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.2, 6.2.5, 4.6.11

Abnormal Pitting Corrosion of 18-8 Stainless Steels in Sea Water. S. Fukui, N. Tagawa and S. Mizuguchi. Paper before Symposium 97th Corrosion Prev., Nov. 26, 1957. Corrosion Engineering, **7**, No. 4, 215-218 (1958) July.

Experiment was carried out to study an abnormal pitting corrosion of austenitic stainless steels in sea water for one year. Stainless steels were abnormally corroded by pitting at the points where sea shells were attached. Most specimens suffered from an abnormal pitting corrosion by attached shells except 18-12 Mo-Cu and 18-12 Mo-Ti stainless steels which demonstrated a considerable resistance to it. Both Smith's ferric chloride test and Streicher's pitting acceleration test were unable to predict the occurrence of the abnormal pitting corrosion.—INCO. 19745

3.2.2, 6.2.5

Pitting Corrosion of Stainless Steel. N. D. Tomashov, N. P. Zhuk and N. K.

Kernich. pp. 584-602 of "Production and Further Processing of Steel and Alloys. Collection of Papers, No. 38, Moscow Steel Institute," 1958. Metallurgizdat, Moscow, USSR.

Measurement of the electrical potential that destroys the protective surface layer of the sample surrounded by a corrosive medium. Factors that influence pitting such as composition, pH number and temperature of electrolyte. Alloying elements improving or decreasing corrosion resistance. 17 references.—RML. 19563

3.2.2, 3.5.3, 7.1

Surface Deformation and Pitting. (In German.) A. Bartel and E. Kuss. Freiberger Forschungshefte, **B35,** 112-128 (1959) Aug.

Destruction caused by micropitting on a gear of a 20,000-ton turbine. Polished microsections of the damaged area showed conical cavities caused by pitting wear. The lubricant applied penetrates into the cavities and exerts additional stress on the cavity during revolution. Different oils tested produced varying degrees of wear. 37 references.—RML. 19632

3.2.2, 5.9.2, 5.3.4

Avoiding Embrittled Springs. D. J. Fishlock. Mech. World, **1959,** 107-108, March.

The writer gives a short account of some sources of hydrogen embrittlement of steel, with special reference to high tensile steel. Certain precautionary measures minimize failure due to acid pickling, an oxidizing pickle of nitric or chromic acid being useful. Since electroplating with zinc tends to seal in occluded hydrogen, a non-embrittling pickle or mechanical de-scaling process such as vapour honing is recommended. For cadmium plating a fluoborate solution is said to eliminate embrittling almost entirely and vacuum coating eliminates it altogether. Good results are also claimed for a Kanigen nickel/phosphorus-alloy preliminary deposit.—ZDA. 19739

3.2.3, 6.2.3

Nature and Mechanism of Formation of Surface Layer on Arsenic-Containing Steel. (In Russian.) P. I. Kuleshov and I. I. Chaika. Fizika Metallov i Metalloved, **7,** No. 1, 91-94 (1959). Translation available from Henry Brutcher, Technical Translations, P. O. Box 157, Altadena, Calif.

Nature of thin surface layer enriched in arsenic, formed on arsenic-containing carbon steel when exposed to high-temperature oxidation. Results of micrographic study. Formation of arseniferous ferrite. Reason for concentration of arsenic in front of wustite layer during scaling. Particulars on mechanism.—TT. 19263

3.2.2, 6.2.2, 6.3.10

Corrosion Embrittlement: The Effect of Cathodically Evolved Hydrogen on Iron and Nickel. M. Smialowski. Paper before Soc. Chemical Industry, Corrosion Group, October 1, 1958. Chem. & Ind., No. 35, 1078-1083 (1959).

Hydrogen is usually introduced into the metal by cathodic charging, resulting embrittlement being measured in an apparatus where embrittled wires are twisted and number of rotations required to snap the wire measured. This measurement gives a value for a parameter called "brittleness." In the case of Fe and steel, cathodic charging produces a

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progressive and irreversible elongation of the metal specimen until a steady value is reached after some hours. Very little elongation takes place on cathodically surcharging Ni. However, hydrogen does enter the metal to some extent since with a suitable design of apparatus the bending of a nickel plate cathode can be observed. Since diffusion rate of hydrogen in nickel is much lower than that in iron and mild steel, cathodically-evolved hydrogen does not penetrate deeply into nickel. With Fe, however, the combination of monatomic hydrogen inside the metal can form blisters near the metal surface and blow-holes deeper within the surface. This action explains the irreversibility of the elongation of steel.—INCO. 19485

3.2.2, 3.5.8, 3.7.3

Hydrogen and Segregates in Flaking. T. E. Scott and A. R. Troiano. Case Inst. Technology. J. Metals, **11,** No. 9, 619-622 (1959) Sept.

Two most generally accepted theories of flake formation — Transformation Stress Theory and Hydrogen Pressure Theory—are discussed with particular reference to stresses caused by alloy segregation. Means of producing flake-free steel sections are suggested. Experiments were made on steels corrsponding to SAE 4140, 8640, 4340 and 5140, fabricated into composite specimens, using laboratory technique which is described. Transformation/time curves were established. Results are discussed in terms of heat-treatment and microstructures observed. By virtue of their inability to respond to normal heat treatment, segregates remain austenitic and become enriched with hydrogen, which is rejected from surrounding matrix during transformation. This enrichment, together with high transformation and thermal stresses induced during cooling, makes these segregates extremely susceptible to flake formation. Mixed microstructures containing relatively small amounts of martensite are more sensitive to flake formation than microstructures consisting of higher percentages of martensite. Any heat treatment which completes decomposition of austenite above M_s with concomitant outgassing, prior to cooling to room temperature, will mitigate or eliminate possibility of subsequent flake formation. General behavior of flaking permits this phenomenon to be catalogued as a special case of hydrogen embrittlement. Illustrations, 18 references.—INCO. 19482

3.2.2, 3.4.3, 3.4.6, 4.6.4, 5.8.1

Corrosion Pitting—How Does it Form? G. G. Sindery. Modern Power and Eng., **53,** No. 8, 58-59, 116-117 (1959) Aug.

An explanation of sequence of events which occur during formation of pitting. An examination of corrosion products from a pit will show that outer layers consist of ferric hydroxide and that inner layers are composed of ferrous salts and black magnetic Fe oxide with some ferric oxide in outer layers and none at seat of pit. Effect of pH and of dissolved substances on electrolytic action is considered. Oxygen and CO_2 are chief causes of corrosion of metals in contact with water. Discussion of water treatment methods covers 3 main categories: internal, external, and conditioning. Corrosion inhibitors lie in third category. For cooling waters where dissolved oxygen is always present, external and internal treatment methods must be supplemented by inhibitors in order to offset corrosive effect of oxygen and to adjust pH value. —INCO. 19469

3.2.2, 6.2.3, 4.6.2

Carbon Steel Has Its Problems, Too; When Piping Steam at 800 F. I. A. Rohrig. Detroit Edison Co. Heating, Piping and Air Conditioning, **31,** No. 6, 108-111 (1959) June.

Graphitization is not limited to C-Mo steel piping materials; same problem occurs in C steels in which severe cases of graphitization have been found at 800 F. In sampling C steel piping to determine its graphitized condition, other significant findings have been made, such as cracking (due to combined action of corrosion attack and fatigue stress) of internal surfaces at desuperheaters, flow meters, and drain connections. In graphitization exploratory program, many of valve castings showed low ductility and cracked readily in small weld prober samples. Weld repairs and heat treatment of valve ends at 1700-1750 resulted in no warping problems in Cr-Ni-Mo and C-Mo alloy steel valves. Cr-Ni-Mo steel did not graphitize. Photographs.—INCO. 19445

3.2.3, 3.5.9, 6.2.2

On the Oxide Films and Scales of Fe-Si-Al System Alloys at High Temperature. (In Japanese.) Masataka Sugiyama and Tadayuki Nakayama. Corrosion Engineering, **8,** No. 11, 463-467 (1959) Nov.

Oxide films and scales produced on surface layers of Fe-Si-Al alloys (ca. 1 ~ 6 per cent Si — 1 ~ 7 per cent Al) in contact with air at 700 ~ 1200 C were studied by electron diffraction, X-ray and metallurgical microscopic methods. Special heat-resisting films of amorphous SiO_2 or fine Al_2O_3 crystals were formed on the Fe-Si-Al alloys surfaces in the earliest stage of oxidation (temp. 700 C and 1000 C). At 1100 C the 6 per cent Si-Al-Fe alloy was covered with SiO_2 crystals; at 1200 C crystal layers of Fe_2SiO_4 were noticed. The eutectic point of Fe_2SiO_4 and FeO phases (1170 C) shows that heat-resistance falls remarkably around 1200 C. 19528

3.4 Chemical Effects

3.4.3, 3.4.7, 3.2.3, 6.3.19, 6.3.6

Studies on the Influence of Chemical Factors on the Corrosion of Metals. W. Feitknecht. Paper before Corrosion Group, Soc. Chem. Ind., London, April 14, 1959. Chemistry and Industry, No. 36, 1102-1109 (1959) Sept. 5.

The corrosion of zinc and copper in air and in solution is described, based on a study of the corrosion products. Variations in pH, for example, lead to the formation of two different types of zinc hydroxide i.e. β, and $\beta 2$, on ageing at pH 7-9 and 11-12 respectively. The behavior of oxide films in an atmosphere containing hydrogen chloride and water vapor is considered, also corrosion in aqueous sodium chloride solutions. Some mention is made of the behavior of cadmium under various conditions. 5 figures, 12 illustrations.—ZDA. 19735

3.4.7, 6.3.19, 6.2.2

Correlation Between the Corrosion of Metals and the pH Value of Solutions. (In Czech.) K. Smrcek. Korose a Ochrana Materialu, **3,** No. 5-6, 57-59 (1959).

Basic relationships between corrosion of metals and pH values of solutions. Individual relations for diluted solutions with a pH of 1-14. Dependence of corrosion degree of Zn and Fe on the pH of the solution and surface conditions of the specimen. 11 references.—RML. 19457

3.4.9

Corrosion by Condensed Water. (In Russian.) I. L. Rozenfeld and K. A. Zhigalova. Zavodskaya Lab. (Factory Lab), **25,** No. 2, 172-174 (1959). English Translation of Journal available from: Instrument Soc. of America, 313 Sixth Ave., Pittsburgh 22, Pa.

Corrosion of low-carbon steel caused by condensed water is influenced by the shape of condensed water (droplets or continuous film) and is promoted by periodical drying and the presence of SO_2 or salts such as NaCl.—RML. 19430

3.4.3, 6.3.14

Observations on the Corrosion Products of Tin. T. K. Ross and W. Harris. Corrosion Technology, **6,** No. 9, 269-271 (1959) Sept.

Thorough investigation of physical form of corrosion products formed in surface-active Na primary dodecyl sulphate, and of factors controlling their formation. Existence of various types of corrosion product was evident. These are dependent upon concentration of solution and are unaffected by surface condition of tin. In concentrated solutions, products build up into hollow hemispheres as result of influence of cathodic alkali on precipitation. Absorption of surface-active agent on initial corrosion products restricts further oxidation to higher valency state. At lower concentrations, initial precipitation of soluble anolyte is more rapid and deposits are more crystalline. In very dilute solutions, deposits develop into filaments which grow in length until they break away. Within a narrow concentration range, marked changes occur from relatively smooth-surfaced products to more crystalline types, due to formation of miscelles near this concentration region. 8 references.—INCO. 19429

3.4.8, 8.8.1

The Effect of Chloride on the Design and Operation of Nitric Acid Recovery Facilities. Process Engineering Report. F. G. Walters, F. W. Winn and H. H. Bulkowski. Catalytic Construction Co. U. S. Atomic Energy Commission Pubn., NYO-1182, October 15, 1953 (Declassified October 7, 1959), 51 pp. Available from Office of Technical Services, Washington, D. C.

The effects of chloride on the design and operation of a HNO_3-recovery facility are summarized. Data are presented on the concentration gradients of chloride ions in fractionators and absorbers, as well as methods for removal of chlorides to eliminate serious corrosion problems.—NSA. 19541

3.4.8, 3.8.3, 3.8.4

Anaerobic Corrosion of Metals in Solutions Containing Various Metallic Cations. Inactivation and Activation. (In English.) W. R. Buck and H. Leidheiser. Z. Elektrochem., **62,** No. 6/7, 690-695 (1958).

The following metals are inactivated (corrosion reduced) by ions in solution: Fe by Sn (II) and Pb (II) ions in boiling 0.2M citric acid, Ni by Cu (II) ions in boiling 2M HCl and Ti by Pt metal ions in boiling 2M HCl. The metals Al, Cu, Fe, Ni, Ag, Zn and Sn are activated by Pt metal ions in solution. There is

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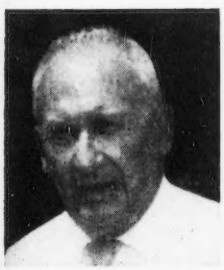

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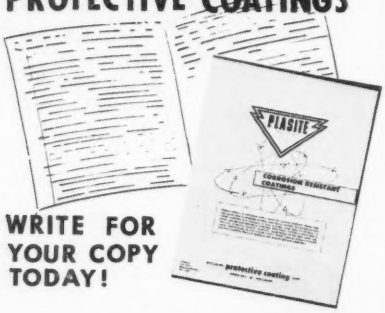

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evidence that the metal in solution is plated on to the surface of the corroding metal and activates it or deactivates it depending on the type of intermetallic binding occurring at the surface. 13 references.—PMR. 19731

3.5 Physical and Mechanical Effects

3.5.8, 6.2.4

The Corrosion Resistance, Especially the Corrosion Fatigue, of Nitrided Titanium Steel. (In German.) M. Tömöry. Technischen Universität, Budapest. Periodica Polytech. (Eng.), **2**, 291-308 (1958).

A corrosive action, together with repeated stress, leads, in steel, to severe pitting. The corrosion fatigue strength of high strength and of soft steel was compared. From the standpoint of the corrosion fatigue, it is very advantageous for steel to withstand compressive stress. The internal compressive stress of the titanium steel investigated was 40 kg/mm². Its bending strength under alternating load was 45 kg/mm² in both aid and water. In salt water the fatigue limit was smaller. The corrosion strength of nitrided carbon steel is somewhat smaller and the corrosion-proof phase much narrower than that of nitrided titanium or Cr-Al-Mo steel. (tr-auth)—NSA. 19565

3.5.9, 6.2.2, 3.2.3

The "Supertemperature" Which Appears During Scaling of Pure Iron and Its Theoretical Explanation. (In German.) Norbert G. Schmahl, Hans Baumann and Hermann Schenck. Arch. Eisenhuttenwesen, **29**, 41-46 (1958) January.

"Supertemperature" is defined as the excess temperature of the specimen over the ambient temperature of furnace. Through new experiments a mathematical description of the temperature curve in dependence of time was made possible. A graphic method permits the determination of the constant of heat transfer and the temperature of the specmien. 10 references.—MR. 19497

3.5.4, 8.4.5

Influence of Radiation Upon Corrosion and Surface Reactions of Metals and Alloys. M. T. Simnad. pp. 126-143 of "Effects of Radiation on Materials," 1958. Reinhold Publishing Corp.

Changes in metal properties and changes in composition of ambient environment which result from nuclear irradiation and which influence surface reactions or corrosion. Corrosion of fissionable and nonfissionable metals in nuclear reactor by water or aqueous solutions. Influence of irradiation on gas-solid reactions; effect of proton radiation upon surface reactions. 34 references.—RML. 19492

3.5.5, 6.3.20, 4.6.2, 8.4.5

Hydrogen Permeation of Zircaloy-2 Corrosion Films. R. F. Boyle and T. J. Kisiel. pp. 31-44 of "Bettis Technical Review, No. 10, Reactor Metallurgy" October, 1958. U. S. Atomic Energy Commission Pubn., WAPD-BT-10. Available from Office of Technical Services, Washington 25, D. C.

Determination of the effect of H_2 pressure during normal 750 F steam corrosion to simulate in-pile failures. Zircaloy-2 with a corrosion film will hydride completely in a pure hydrogen atmosphere and in a hydrogen-steam mixture if the hydrogen-to-steam pressure ratio is greater than 104-to-1 when the temperature is 343 C. 12 references. —RML. 19657

3.5.8

Experimental Investigation of Some Processes Involved in Fretting Corrosion. J. S. Halliday. (Inst. Mech. Eng.) Conf. on Lubrication and Wear 1957, **1958**, 640-646.

Tests were made on Al, Duralumin, Cu, Ni and mild steel to isolate the mechanisms arising in fretting corrosion. Fretting causes breakdown of the natural oxide films and leads to the formation of intermetallic welds. In the absence of lubricant, oxidized debris accumulates. In oil intermetallic welding continues and, while corrosion is insignificant, no appreciable lubrication occurs. 14 references.—MA. 19771

3.5.4

The Effect of Ion-Bombardment on the Corrosion of Metals Under Atmospheric Conditions. (In Russian.) A. V. Byalobzheskii. Inst. of Physical Chemistry, Academy of Sciences, USSR. Zhur. Fiz. Khim., **33**, 1256-1262 (1959) June.

It was demonstrated experimentally that fast electrons, X-rays, and γ rays at intensities corresponding to energy absorption of not less than 10^{14} ev/liter air lead to a multiple increase in the rate of corrosion of iron, copper, zinc and aluminum in a moist atmosphere. This is the result of the appearance in the atmosphere of radiochemical reaction products such as long living O_3, H_2O_2 and N_2O_5 and especially short living HO_2, OH, NO_3, etc. Being active cathodic depolarizers, these products intensify the work of the corrosion microcouple. The usually inert nitrogen under conditions of irradiation in the presence of oxygen and moisture becomes an active corrosive agent, facilitating the formation of nitric acid. (auth)—NSA. 19645

3.5.8, 5.3.2

Corrosion Fatigue. Its Prevention by Zinc Coatings. G. FitzGerald-Lee. Corrosion Technology, **6**, No. 11, 330-332, 340-341 (1959) Nov.

First example of use of zinc coatings to solve problem of corrosion fatigue arose when wire for towing paravanes in sea water failed due to vibrations which set up cyclic stresses. Later research revealed that joint effect of repeated stresses and corrosion acting together exceeds sum of 2 effects taken singly. Not all cases of corrosion fatigue can be dealt with by zinc protection, but most benefit from zinc coating. Principles of corrosion fatigue are explained, cathodic protection offered by zinc is discussed, and results obtained by various coating methods (electroplating, hot-dip galvanizing, spraying, and use of heavily zinc-pigmented paints) are compared. Table shows effect of corrosion on fatigue strength for various steels, including nickel-containing and stainless steels.—INCO. 19747

3.5.8, 6.2.5, 3.7.4

Stress Corrosion of Single Crystals of Stainless Steel. H. W. Paxton, R. E. Reed and R. Leggett. pp. 181-191 of "Physical Metallurgy of Stress Corrosion Fracture." Metallurgical Society Conferences, Vol. 4, 1959. Interscience Publishers, Inc., New York 1, N. Y.

Single crystals of austenitic stainless steel were stressed in tension in boiling

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magnesium chloride to distinguish between the various proposed theories of stress corrosion. The plane of the crack, the necessity of plastic deformation, nucleation of the crack. 5 references.—RML. 19372

3.5.8, 3.2.2, 6.2.3

Transition from Stress Corrosion to Pitting Corrosion of Mild Steels. (In German.) Wilhelm Radeker. Arch. Eisenhuttenw., **30,** 747-750 (1959) Dec.

A sample was exposed to the action of boiling water containing NH_3, NO_2, NO_3, Cl and Ca while under tensile stress. Both types of corrosion were observed. The degree of tensile loading determines the type of corrosion.—RML. 19416

3.5.9, 3.2.3, 3.7.2, 6.3.6, 6.3.10

High-Temperature Oxidation of (Chromium- and Nickel-Base) Gas-Turbine Alloys. John F. Radavich. Amer. Inst. Min. Met. Eng. Conf. on High-Temperature Materials, 1957, **1959,** 520-537.

The oxidation of many high-temperature alloys proceeds by the formation of a thin film on top of which an oxide scale is nucleated. The effects of Mo, Co and W addition on this corrosion mechanism for Cr- and Ni-base alloys was studied by optical and electron microscopy, reflection and transmission electron-diffraction and by X-ray diffraction and fluorescence. Mo and W are believed to form volatile oxides which cause blistering of the oxide film, and Co merely increases the adherence of the oxide scale.—MA. 19425

3.5.8, 7.1, 6.3.10, 3.5.9

Thermal-Stress Fatigue Cracking of Turbine Buckets Operated at 1700 F (925 C) in a Turbojet Engine with Frequent Starts and Stops. R. A. Signorelli, J. R. Johnston and J. W. Weeton. U. S. Nat. Aeronautics Space Administration, Tech. Note, D-125, 1959, 16 pp.

The following nickel-base materials were tested in a turbojet engine at 1700 F (925 C): investment-cast SEL-1 (Co 27, Cr 15, Mo 2.5, Ti 2.25, Al 3.75 and C 0.1 per cent), B and B (Co 30, Cr 15, Mo 5, Ti 2.5, Al 3, and B 0.5 per cent), Inconel 713 (Cr 12, Mo 4, Ti 0.5, Al 5.5, and Nb 2 per cent), Udimet 500 (Co 15, Cr 20, Mo 4, Ti 3, Al 2.75 and C 0.1 per cent); wrought Udimet 500 alloy. The primary mode of failure on the leading edge of the buckets was thermal fatigue. Forged Udimet 500 and cast B and B cracked after ~ 30 starts, whereas the other alloys cracked after ~ 10 starts. However, the thermal-fatigue cracks did not progress rapidly. Buckets ran with cracks as long as 63 hr. without fracture. —MA. 19491

3.5.4, 8.4.5

Radioactivity in Reactor Coolants. Interim Report. J. E. Stewart. Atomics International Div., North American Aviation, Inc. U. S. Atomic Energy Commission Pubn., NAA-SR-Memo-4057, June 30, 1959, 8 pp. Available from Office of Technical Services, Washington, D. C.

The corrosion rates in the OMRE from coolant activation analysis and radiation measurements were determined. The amount of coolant activity due to the recoil process from the stainless steel fuel elements was investigated. A computer program was prepared for the calculation of coolant activity.—NSA. 19534

3.5.8, 2.3.7, 6.4.2

Stress-Corrosion of Notched and Unnotched 7079-T6 Aluminum Alloy. R. Kegarise. U. S. Wright Air Development Center, Technical Note 59-66, May, 1959, 19 pp.

Specimens were tensile loaded in transverse direction at 90 per cent of smooth tensile yield strength. Alternate immersion techniques in 3½ per cent salt solution were used. Failure times for both notched and unnotched specimens were recorded and per cent loss in tensile strength was determined. Results indicate that notched specimens, which are loaded to same average stress level as smooth specimens, show no increase in stress corrosion susceptibility. Results also show that notched stress corrosion tests do not effectively accelerate results unless liquid retained in notch due to surface tension is removed. There was also an indication that residual stresses built up during machining of notched specimens may play an important role in discouraging stress corrosion attack. Formation of whisker growths on surface of notched specimens is considered. Tables, photomicrographs.—INCO. 19253

3.5.8, 6.2.3

Stress Corrosion Cracking in Low Carbon Steel. Hugh L. Logan. pp. 295-310 of "Physical Metallurgy of Stress Corrosion Fracture." Metallurgical Society Conf., Vol. 4, 1959. Interscience Publishers, Inc., New York 1, N. Y.

Stress-corrosion cracking of 1020 steels and large-grained decarburized specimens in a boiling solution of 20 per cent NH, NO_3; effect of anodic current on stress corrosion rate; effects of plastic deformation, crystal orientation, grain size and composition on stress corrosion cracking. 24 references.—RML. 19273

3.5.3

Cavitation Phenomena. (In German.) H. H. Piltz. Metalloberfläche, **13,** 285-288 (1959) Sept.

Cavitation is considerably accelerated by chemical and electrochemical processes. Hardness, strength and surface workability qualities of the material are of secondary importance in cavitation resistance. The principal factor is the structural condition of the metal.—RML. 19370

3.5.8, 3.2.2

Crack Formation in Steels Under Action of Aqueous Hydrogen Sulphide Solutions. (In German.) F. K. Naumann and W. Carius. Arch. Eisenhuttenw., **30,** 233-238 (1959).

Time-to-cracking of steels subjected to stresses in aqueous hydrogen sulfide depended hyperbolically on the tensile stress in the surface layers and the hardness of the metal. If the metals are equally hard, composition and structure have no effect. If the product of the hardness and tensile strength is less than 21,000 sq/kg./mm.^{4}, no cracking takes place. Cracks are normally transcrystalline. 20 references. 19359

3.5.8, 5.12

Stress Corrosion. (In Japanese.) Yoshizumi Mishima. Metals, **29,** 741-746 (1959) Oct.

Heat treatment of aluminum, magnesium, iron and copper alloys, brass, mild steel and austenitic stainless steel to relieve stress corrosion and electrochemical corrosion. 10 rferences.—RML. 19358

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3.5.9, 3.8.4, 4.2.3, 7.6.4, 7.1

High Temperature Corrosion. C. J. Slunder. pp. 152-168 of "A Review of Available Information on Corrosion and Deposits in Coal- and Oil-Fired Boilers and Gas Turbines," 1959. The American Society of Mechanical Engineers, New York.

Describes mechanism and kinetics of oxidation at high temperatures. Discusses reactions of metals and alloys with products of combustion and corrosion in coal- and oil-fired boilers and gas turbines.—BTR. 19470

3.6 Electrochemical Effects

3.6.2, 6.4.4

On the Mechanism of Metal Corrosion in Narrow Slits and Crevices. Pt. VI. Magnesium and Some of Its Alloys. (In Russian.) I. L. Rozenfel'd and I. K. Marshakov. J. Phys. Chem. (Zhur. Fiz. Khim.), **33,** No. 2, 411-415 (1959) Feb.

A study was made of corrosion in narrow slits in magnesium and some of its alloys. It is shown that in the majority of cases these metals are subjected to more severe corrosion in the slits than in the bulk of the electrolyte. The slit corrosion assumes a more clearly expressed local character. The dependence of the corrosion rate on the size of the slit is expressed by a complicated curve, being characterized by the presence of maxima at definite slit values. The mechanism of the intensified corrosion of magnesium and its alloys in slits rests on the intensive stirring of the electrolyte by hydrogen bubbles and in the motion of the bubbles themselves, obstructing the formation of protective films and destroying existing ones, rather than on the hinderance to the diffusion of oxygen. Hence the intense corrosive breakdown of magnesium in slits is due to the work of microcells and to the change in the intensity of their functioning. The part played by macrocells in the development of "slit corrosion" of magnesium and its alloys, in contrast to the previously studied cases of slit corrosion, does not come to the fore, owing to its low effectivity. (auth)—NSA. 19443

3.6.5, 4.6.11, 3.6.6, 6.2.4

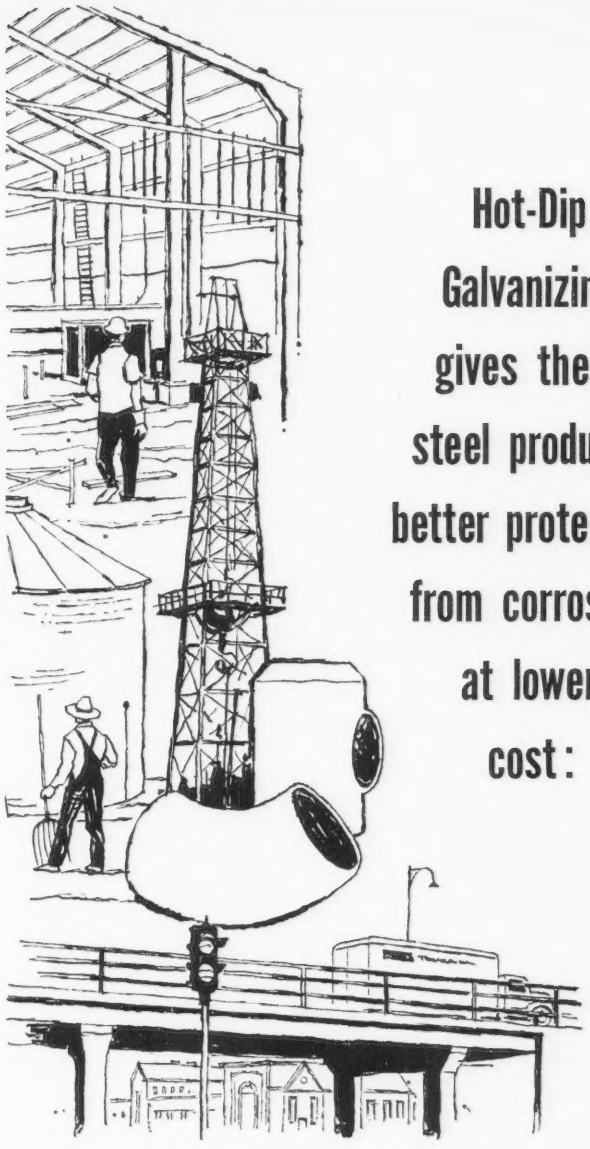
Corrosion Potentials and Galvanic Corrosion of Low-Carbon Steels in Sea Water. (In English.) E. Uusitalo. Suomen Kemistilehti, **32,** No. 10, 222-230 (1959).

Corrosion potentials and current-potential curves of steel of varying composition immersed in sea water were determined. Couples of samples of several compositions were combined with sea water as an electrolyte. 12 references.—RML. 19552

3.6.2, 3.4.7, 6.2.5

Effect of Differential Aeration and of the pH on the Corrosion of Stainless Steel in Narrow Crevices. (In Russian.) I. B. Ulanovskii and Yu. M. Korovin. Inst. of Physical Chemistry, Academy of Sciences, USSR. J. Phys. Chem. (Zhur. Fiz. Khim.), **33,** 1413-1417 (1959) June.

A drop in oxygen concentration in a narrow crevice will, in every case, activate the surface of stainless steel, leading to the formation of a differential aeration couple. However, at normal pH values the current in such couples will quickly diminish, evidently owing to passivation of the anode. The value of



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the pH is one of the main factors determining the intensity of corrosion in the crevice of a metal. In some cases a low pH value will activate the metal surface in a crevice, often leading to intensive destruction due to the formation of strong galvanic couples. In other cases such an effect is not observed. (auth)—NSA. 19555

3.6.8, 6.3.10

Oxygen Overvoltage on Nickel Anodes. (In Russian.) Ya. I. Tur'yan. J. Phys. Chem. (Zhur. Fiz. Khim.), **33,** No. 4, 948-952 (1959).

The behavior of a nickel anode in 7.5 N-KOH at 5 x 10^{-6}-9.0 amp/cm² is discussed, and the results and conclusions are compared with those of other investigators. The η/log i curve has four portions; the longest and most important is at relatively high i values, and is represented by the equation η = constant + RT log i/0.45 F. The mechanisms of oxide formation and types of oxide most probably formed are discussed. 22 references.—MA. 19557

3.6.2

The Role of the Metal-Ion Concentration Cell in Crevice Corrosion. G. J. Schafer and P. K. Foster. J. Electrochem. Soc., **106,** No. 5, 468 (1959) May.

Presents some arguments which suggest that metal-ion concentration cell cannot be a cause of crevice corrosion, and that crevice mouth attack is a special case of differential aeration.—INCO. 19514

3.6.6, 3.6.4

Contact Corrosion Between Metals and Nonmetallic Materials Both in the Atmosphere and in Electrolytes. (In German.) F. Podbreznik. Werkstoffe u. Korrosion, **10,** No. 8, 495-498 (1959) Aug.

Galvanic corrosion of two metals with potential difference; physical contact of two metals by means of infiltration, gaseous and liquid media.

Contact-corrosion systems discussed are: Al/building materials, steel/wood, steel/Cu, glass/steel and metal/paper. 15 references. 19388

3.6.5

The Influence of Corrosion on the Electrode Potential of Alkali-Amalgam Electrodes. (In German.) K. Bräuer and H. Strehlow. Z. physikal. Chem. (Frankfurt), **17,** No. 5/6, 336-345 (1958).

Corrosion effect makes more positive the electrode potential of an alkali-amalgam electrode in contact with the alkali metal ions. The dependence of this effect upon amalgam and electrolyte concentration, and also upon pH and oxygen content of solution is studied. An equation is given with which normal potential and activity coefficient can be calculated from e.m.f. measurements in aqueous and non-aqueous solutions. The measurements given are for K and Rb. 17 references.—MA. 19716

3.6.8, 3.8.2

Overvoltage of the Cathodic Reduction of Oxygen and Activation Energy of the Corresponding Electrochemical Processes. (In Russian.) A. U. Akopyan. J. Phys. Chem. (Zhur. Fiz. Khim.), **33,** No. 7, 1625-1631 (1959).

Akopyan studied the cathodic reduction of O on Hg, Pt, Au and Ag in N-NaOH and 1.0158 N-H_2SO_4 at 0, 20, 40 and 60 ± 0.1 C by the polarization-curve method (the results for Pb were non-reproducible because of the high cathode-oxidation rate). The curves were made up of two linear parts in accordance with Tafel's equations with different a and b coefficients. The first part corresponded to H_2O_2 generation, the second to H_2O formation. From a study of the b values it is seen that the first part of the curve corresponds to concentration polarization in alkaline solution and electrochemical polarization in acid solution. A formula is derived mathematically to correlate current with activation energy, A, and pre-exponential coefficient, B. Values for A and B depend only slightly on the nature of the cathode. 16 references.—MA. 19621

3.6.8, 6.3.19

Overvoltage During Hydrogen Evolution on Zinc. (In Russian.) Li Un Sok, A. L. Rotinyan and N. P. Fedot'ev. J. Phys. Chem. (Zhur. Fiz. Khim.), **32,** No. 11, 2514-2517 (1958).

At low current density the polarization curve does not obey Tafel's equation, but has an inflection at the current density corresponding to the current of self-dissolution of Zn. At higher current density up to 0.7 amp/cm² in N-H_2SO_4 solution, Tafel's equation holds and the slope of the polarization curve is 2.3 RT/0.5 F. The activation energy of hydrogen discharge on zinc was found to be 17.93 kcal/mole. Surface quality affects overvoltage, and values are calculated for electropolished and electrodeposited zinc.—MA. 19549

3.6.8, 6.3.10, 6.4.2, 3.8.3

Polarization of Nickel and Aluminum in Neutral Solutions. J. H. Greenblatt and E. M. Levy. J. Applied Chem., **9,** No. 5, 269-273 (1959) May.

Cathodic polarization of Al, 2S Al, Ni, Al-2 percent Ni alloy, and Ni-plated Al (Al:Ni = 1:1 and 10:1) was studied under H- evolution conditions in 3.17 percent KCl solution. Polarization increased with temperature in the case of Al, but decreased for Ni, Al-Ni alloy, and Ni-plated Al. Corrosion-resistance of Al-Ni alloy is probably due to passive-film formation, rather than decreased H penetration.—MA. 19746

3.7 Metallurgical Effects

3.7.3, 6.3.15

Inert-Gas Tungsten-Arc Welding of Titanium for Nuclear and Chemical Industries. G. M. Adamson and W. J. Leonard. Paper before American Welding Society, Annual Spring Meeting, St. Louis, April 14-18, 1958. Welding J., **37,** No. 7, 673-682 (1958) July.

Describes procedure developed for field welding commercial unalloyed titanium pipe and plate using conventional inert-gas tungsten-arc equipment. Procedure depends upon maintaining low temperatures and careful control of torch and backing inert gas during welding operation. By using filler wire of higher purity than base metal, weldment with uniform mechanical properties is achieved. Price and quality of titanium welds made by this technique are comparable to those in which stainless steel is welded for nuclear applications. Techniques have been proven in construction of several titanium loop systems. Tables.—INCO. 19605

3.7.3

Solder Bonding Aluminum to Uranium. H. M. Mishler, J. T. Nieman, R. P. Sopher and D. C. Martin. Welding J., **38,** No. 6, 268-s-272-s (1959) June.

This study was undertaken to determine if flat-plate fuel elements could be produced by solder bonding aluminum sheets to a uranium core. It was necessary to plate the uranium with chromium, iron or nickel, which served as a diffusion barrier. The solders used were lead, tin, zinc and their alloys. No provision was made for removing surface oxides on the base metals. Therefore, it was necessary to plate the aluminum and uranium diffusion barrier. The best bonds were produced with aluminum plated with 0.5 mil of copper and nickel-plated uranium given a copper flash. Corrosion tests on bonded samples showed zinc was the most corrosion-resistant solder tested. Successive samples made with like solders sometimes varied in joint quality. A greater variation would probably exist in larger samples made under mass-production conditions. (auth)—ALL. 19319

3.7.3, 8.1.1

Unusual Fastening Techniques for Air Conditioners. F. Savaglio. Assembly and Fastener Eng., **1,** No. 7, 28-30, 32, 34 (1959) April.

Along with 2 major problems—providing interior accessibility and preventing corrosion—ever-present problems of using a fastener that is economically feasible and that expedites production assembly operations must be solved. Most of tapped rivets used are of anodized aluminum material, which is highly resistant to most corrosive influences. Brass tapped rivets are used in a hot-dipped galvanized assembly to avoid possibility of galvanic corrosion. Joining coil pan to an air cooling component with stainless steel staples avoids corro-

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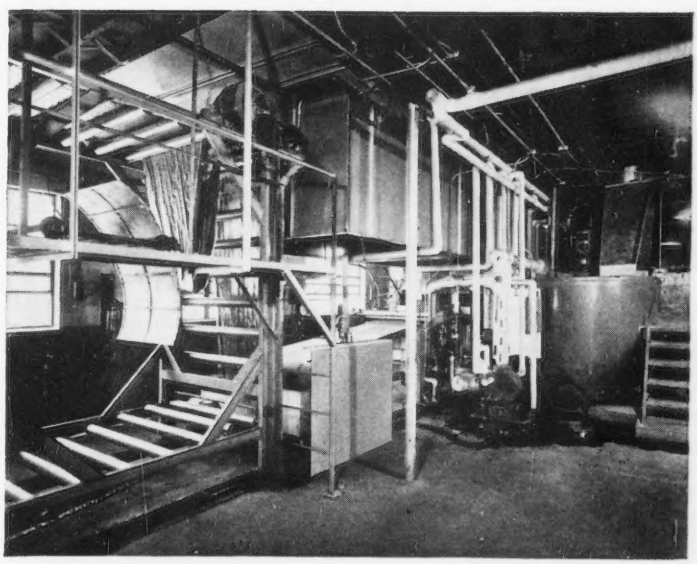

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sion possibilities. Problem of mounting a replaceable filter in one unit where it would be almost impossible to reach it with any type of tool was solved by using small Alnico magnets to hold filter in place. Brazing and welding applications are discussed. Photos.—INCO. 19473

3.7.3, 5.11

Joint Design for Automatic Welding Eliminates Cracking and Porosity. A. J. Rosenberg and E. W. Jamison. General Electric Co. Welding Design and Fabrication, **32,** No. 7, 32-34, 52-53 (1959) July.

Good joint design and correct welding technique minimize cracking and porosity in automatic consumable electrode welding of forged and heat treated AISI 4340 steel hub to cast Co-base high temperature alloy bucket in production of high speed turbine wheel. Filler metal is Type 19-9 WMo (Type 349). Types of cracking (radical, fusion line, transformation and centerbead), their causes and methods of avoiding their occurrence, are discussed. Diagrams show evolution of joint design.—INCO. 19437

3.7.3, 6.3.13

Argon-Arc Welding of Tantalum. (In Russian.) F. E. Tetr'yakov, I. K. Rogozhkina, V. I. Konstantinov and Ya. M. Polyakov. Svarochnoe Proizvodstvo, **32,** No. 8, 5-7 (1959).

Experiments showed that tantalum may be satisfactorily A-arc welded with a tungsten electrode with a.c. direct polarity, arc voltage 8-12 V, and current 65-350 amp with a 1-3-mm diameter electrode for thicknesses of 0.5-3.8 mm. The area of the joint must be protected from both sides of the weld; from the reverse side by passing A (99.98 percent) through a copper backing strip. The mechanical properties and corrosion-resistance of welded joints and base metal are almost identical in the annealed state.—MA. 19577

3.7.4, 3.5.8, 6.4.2

Stress Corrosion and Type of Grain Boundary. (In German.) F. Erdmann-Jesnitzer and G. Hötzsch. Werkstoffe u. Korrosion, **11,** No. 4, (Suppl.) 212-216 (1960) April.

An Al Mg alloy made corrosion-chemically sensitive through previous heat treatment has been examined in respect of its stress corrosion behavior in order to ascertain which of the types of grain boundary are sensitive to corrosion. It was found that large angle grain boundaries normal to the tensile stress are particularly liable to be attacked. It is, in fact, clear that large angle grain boundaries where heterogeneous efflorescence occurs are particularly prone to fissurize and represent the initial intercrystalline condition for subsequent intercrystalline stress corrosion phenomena. 19733

3.7.3, 6.2.5

Corrosion Observed in Weldments of Stainless and Heat Resistant Steels. (In Czech.) Josef Nemec. Zvaranie, **7,** 193-196 (1958) July.

"Knife-cut" corrosion occurs with stabilized 18-8 steels, near the contact line between weld and base metal. Observed under boiling HNO_3, HNO_2 solutions and NaF. Favored by more than 0.08-0.10 percent carbon in steel; nickel near upper limit, chromium and titanium or niobium near lower limits; coarse grain at contact line. Reduced by increased titanium or niobium; several welded layers not exposing contact line. Stress-corrosion avoided by choice of steels and relief annealing. Slag from coated electrodes causes corrosion by passing atmospheric O and S to the metal and should be removed by sand-blast. 7 references.—MR. 19340

3.7.3, 8.9.5

Corrosion on Welded Seams on Under-Water Hulls. O. Thome-Johannesen. Europ. Shipbldg., **7,** No. 4, 97-100 (1958); J. Brit. Shipbldg. R. A., **13;** No. 12, 729-730 (1958).

Theories on corrosion on welded seams are critically discussed, and a case of corrosion recurring at the painted welds on the underwater plates of a ship is discussed in detail. 19570

3.7.3, 6.3.20

Substitution of Argon for Helium in Controlled Atmosphere Welding. Harold E. Soisson. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-AME-14, October 20, 1958, 8 pp. Available from Office of Technical Services, Washington, D. C.

Specimens of Zircaloy-2 were welded in helium and argon atmospheres to compare the effects. After the welding operations the specimens were subjected to bend and corrosion tests and were examined by X-ray radiography. On the basis of these tests it was recommended that welding techniques be further developed using argon as the blanketing atmosphere.—NSA. 19567

3.7.4, 3.2.2, 6.2.2, 4.6.5

Influence of Crystallographic Orientation on the Pitting of Iron in Distilled Water. Jerome Kruger. J. Electrochem. Soc., **106,** 736 (1959) Aug.

Surfaces of Armco iron and a purer iron having an orientation near the [110] plane showed greatest amount of pitting. Pitting was lower for the purer iron.—RML. 19256

3.7.3, 8.4.5

Application of Electroless-Nickel Brazing to Tubular Fuel Elements for the N. S. Savannah. Status Report. J. T. Lamartine and W. C. Thurber. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-59-6-55, June 2, 1959, 31 pp. Available from Office of Technical Services, Washington, D. C.

The feasibility of using electroless nickel, a chemical deposit containing about 10 wt. percent phosphorus in nickel, as the brazing alloy for assembling tubular stainless steel fuel elements of the type specified in Core I of the N. S. Savannah was investigated. This material was selected primarily because of the ease of braze-metal preplacement by chemical deposition of the alloy on Type 304 stainless steel ferrule spacers, prior to fuel-bundle assembly. Brazed joints produced by this method were generally characterized by a relatively ductile solid-solution region at the thinnest portions of the fillet. This ductile zone should minimize the possibility of complete propagation of hairline cracks, which form in the brittle, eutectic regions of fillet. The microstructural appearance of the electroless-nickel joints was not appreciably affected by variations in the brazing temperature from 1750 to 1900 F for the brazing time from 15 to 60 min. Corrosion tests conducted in static 525 F water indicated that no significant attack of joints brazed with electroless nickel had occurred after 300 hr. exposure. A small fuel bundle was successfully assembled by brazing with electroless nickel. (auth)—NSA. 19283

3.8 Miscellaneous Principles

3.8.3, 6.3.15

Anodic Passivation of Titanium. (In German.) J. B. Cotton. Werkstoffe u. Korrosion, **11,** No. 3, 152-155 (1960) March.

The excellent corrosion resistance of Ti results from the presence of a protective film of oxide at the metal surface. The oxide film is stable in oxidizing solutions but not in acids that do not contain readily available O.

The general corrosion behavior of Ti is also interpreted by reference to a Pourbaix diagram in which potential is plotted against H^+ ion concentration. This indicates regions of stability for titanium dioxide.

Experimental evidence is then produced to show that by raising the electrical potential of the metal, Ti can be made to resist corrosion in non-oxidizing acids. The experimental method used, employing a potentiostat, is described and the polarization graph for Ti immersed in 40 percent H_2SO_4 at 60 C is shown.

The extent to which Ti can be protected by anodic passivation in H_2SO_4 over a range of acid strengths and temperatures is shown.

Finally, the practical application of anodic passivation is illustrated by employment of a welded Ti tank, pipe-line and pump, which has been employed to circulate hot strong H_2SO_4, without any evidence of corrosion. Complete protection was achieved by impressing a d.c. current at 2.3 volts between the tank as anode and an insulated Ta cathode. Current consumption was only 3 watts per M^2. 19727

3.8.3, 6.3.8

Studies on the Passive Film of Lead. (In Japanese with English Condensation.) M. Maeda. J. Electrochem. Soc., Japan, **26,** No. 12, 610-615 (1958) Dec.

In previous papers (J. Japan. Inst. of Metals, **22,** 1958), the author pointed out that the passive oxide of lead, lead dioxide, can be formed by the following reaction: $Pb + 2H_2O = PbO_2 + 4H^+ + 4e$ . . . (1) apart from the well known reaction: $PbSO_4 + 2H_2O = PbO_2 + SO_4^{2-} + 4H^+ + 2e$ . . . (2) In the present paper, the conditions of formation of this oxide, its growth and dissolution rates and its structure are discussed.

Experimental results: (1) Flade potential of lead is lower than oxidation potential of $PbSO_4$; and, at this potential, orthorhombic PbO_2 (α-PbO_2) is formed in addition to the well-known tetragonal PbO_2 (β-PbO_2). (2) Passivity was shown to be principally due to the formation of α-PbO_2. (3) Flade potential of lead was nearly equal to formation potential of α-PbO_2. (4) The rate of dissolution of α-PbO_2 film was expressed by the following equation:

$$\log i_K = -4.76 - 0.04\,pH$$

(5) The rate of growth of passive film followed the so-called inverse logarithmic law under potentiostatic conditions. 19307

3.8.2, 3.6.5

The Electrochemical Behavior of the Nickel-Nickel Oxide Electrode. Pt. I. Kinetics of Self-Discharge. B. E. Conway and P. L. Bourgault. Paper before Symp. on Charge Transfer Processes.

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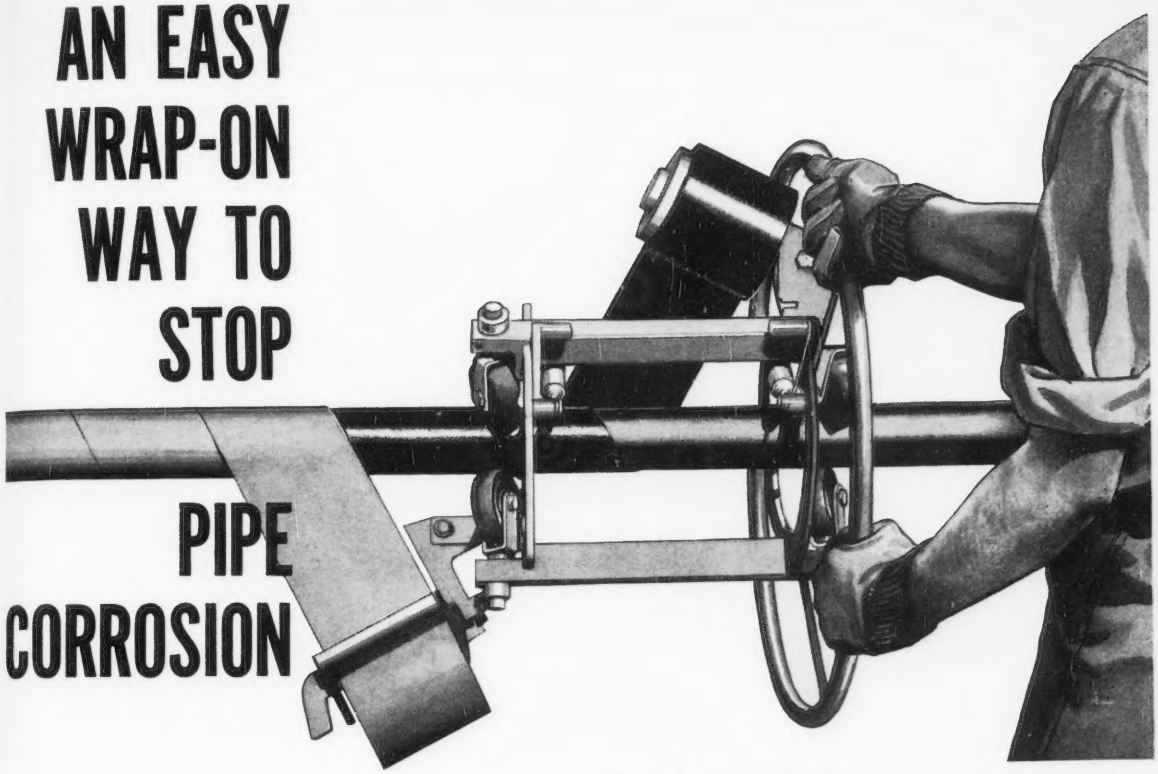

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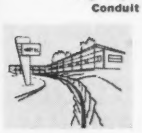
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Univ. Toronto, September 4-5, 1958. Can. J. Chem., **37**, No. 1, 292-307 (1959) Jan.

Ni-NiO electrode forms positive plate in charged Ni-Cd battery. After charging electrode to chemical state represented by non-structural formula NiO_x, where x varies from 1.4 to 1.8 depending on current density and temperature, loss of oxygen, and fall of potential on open circuit occurs. In present work this "self-discharge" effect was examined by study of rate of decay of e.m.f. on open circuit, rate of oxygen evolution on open circuit, electrochemical capacity of electrode, and build-up or charging curves for electrode. Decay behavior was studied in aqueous KOH solutions of 0.0015-15M. Tafel slopes are obtained from plots of e.m.f. vs. log (time of decay), and abrupt changes occur at certain electrode potentials which indicate changes of rate-determining mechanism in self-discharge process. Slopes observed are interpreted in terms of new scheme of consecutive reactions for anodic oxygen evolution by deducing, by means of Christiansen method, the relevant Tafel slopes. Dependence of rates of self-discharge upon OH^- ion and water activity is deduced and significance of results discussed. Tables, graphs.—INCO. 19701

3.8.2, 3.6.8, 6.3.11

Investigation of Polarization Phenomena at Electrodes of Smooth Platinum by Using Charging Curves. J. Giner. Z. Electrochem., **63**, No. 3, 386-397 (1959).

By using resting potential measurements (ε), charging curves and post-polarization curves, the behavior of platinum electrodes in normal sulfuric acid was investigated in the absence of current, and under anodic and cathodic conditions. Measurements show that the electrode behavior is determined by chemisorbed oxygen, not by specific oxides. The degree of oxygen cover was determined from the charging curves. Resting potential increased with coverage which was produced by anodic charging or chemical oxidation with H_2CrO_4 and which was reduced by cathodic charging. Double steps occurred in the anodic charging curves of heavily covered electrodes. Chemisorption of atomic hydrogen occurred before the evolution of hydrogen. The reaction $Pt + H^+ + e^- \rightarrow$ Pt-H had no overvoltage, but the reaction Pt-H $\rightarrow$ Pt-$H_2 \rightarrow$ Pt + H_2 was very slow. The reaction $Pt + H^+ + e^- \rightarrow$ Pt-H in neutral and alkaline solution also showed an overvoltage. The effect of an oxygen atmosphere on platinum electrodes in the absence of current and when charged was investigated.—PRM. 19749

3.8.2, 6.3.21

Study of the Capacitance of Germanium Electrodes. (In Russian.) E. A. Efimov and I. G. Erusalimchik. J. Phys. Chem., USSR (Zhur. Fiz. Khim.), **33**, No. 2, 441-446 (1959).

From a study of the differential capacitance (Q) of p- and n-type Ge the null-charge potential of Ge was found to be independent of the type of conductivity and equal to —0.6V on the H scale. Q of Ge at c.d. of 10^{-5}-10^{-1} amp/cm^2 depends on the type of conductivity and p-type Ge shows two maximum on the current/voltage curve, whereas n-type Ge shows only one maximum. Q also depends on the specific resistivity of Ge. On the basis of visual examination of specimens, the authors assumed that at ~0.5 V an oxide film forms on the surface of Ge.—MA. 19755

3.8.2

Remarks on Corrosion Diagrams. (In German.) V. Cupr and J. B. Pelikán. Werkstoffe u. Korrosion, **10**, No. 9, 544-547 (1959).

A mathematical demonstration that in corrosion curves of the type used, for example, by Akimov, it is not justifiable to superimpose current/voltage curves or to sum partial voltages and currents. 16 references.—MA. 19762

3.8.2, 3.6.8, 3.7.4, 6.3.14

Cathodic Reduction of Oxygen as a Function of Crystal Orientation and Structure of the Electrode. Pt. III. A Study of the Electrode Processes on Tin. V. N. Nikulin. J. Phys. Chem. (Zhur. Fiz. Khim.), **32**, No. 7, 1451-1456 (1958). (In Russian.)

By constructing polarization curves every 10 minutes during the polarizing run and simultaneously determining the amount of hydrogen peroxide and oxygen generated, Nikulin studied the behavior of single-crystal and polycrystalline tin. On (101) planes of polycrystalline tin there is simultaneous formation of hydrogen peroxide and water down to —0.7 V. Below that potential (ϕ) only water is formed. On (211) planes, water is formed at high and low values of ϕ and a hydrogen peroxide-water mixture is formed in between. Oxygen reduction overvoltage is higher for (101) plane than for (211). In the case of a tin single crystal water is formed on (110) plane at the intermediate, and hydrogen peroxide-water mixture at high and low, values of ϕ, while on (001) plane hydrogen peroxide-water mixture is formed at all values of ϕ. Oxygen reduction overvoltage initially is higher on (110) plane, but below —0.55 V the overvoltage is higher on (001) plane.—MA. 19343

3.8.4

Corrosion. E. C. Potter. Reports on the Progress of Applied Chemistry, **43**, 281-288 (1958).

Recent developments reveal that the fields of dry oxidation and immersed corrosion overlap in concept and mechanism. Studies establish the importance of ion-adsorption in the process of oxide-film thickening.—RML. 19386

3.8.2

Electrochemistry of Semi-Conductors. (In Russian.) Yu. V. Pleskov. Khim. Nauka i Promyshlennost', **3**, No. 4, 443-448 (1958).

Adsorption of oxygen and halides on germanium creates a negative change, while adsorption of H_2O, SO_2, NH_3 oriented with the positive end of the dipole towards Ge creates a positive charge. The Ge/gas boundary is thus a condenser and charge distribution is similar in structure to a diffusion double-layer on the metal/electrolyte boundary. During anodic polarization Ge dissolves as a divalent ion, but at higher current density the reaction products (GeO) are not removed from the cathode. p-type Ge obeys Tafel's equation, while on n-type Ge the current increases initially in accordance with Tafel's equation, and then the diffusion of holes from the body of the semi-conductor retards i increase up to a certain ϕ value, after which i increases slowly again. The potential of the germanium electrode is resolved into four components which are described. Although germanium cannot be deposited alone from aqueous solution because its overvoltage exceeds that of hydrogen, it can be co-deposited with other metals. 20 references.—MA. 19395

3.8.2, 3.8.4, 3.6.8

Electrochemical Calorimetry. J. M. Sherfey and A. Brenner. J. Electrochem. Soc., **105**, No. 11, 665-672 (1958).

The heat effects of electrochemical processes have been measured calorimetrically to find those areas where such measurements might prove useful. The determination of reaction heat (ΔH) is one such area. The ΔH of the reaction $W + 2H_2O + 2NaOH\ (aq) = Na_2WO_4\ (aq) + 3H_2$ was measured. The results indicate that the heat of formation of Na_2WO_4 (aq) given in the literature is in error by at least 12 kcal. The heat of the reaction $Cu^o + nCN^- + H_2O = Cu(CN)_n^{(n-1)-} + OH^- + \frac{1}{2} H_2$ was determined as a function of the cyanide to copper ratio of the electrolyte. These data confirm the existence of the Cu $(CN)_4 \equiv$ ion.

Another application for such measurements is in studies of electrode polarization. Equations are derived which show the relation between polarization and the other heat-producing phenomena in electrolytic cells. This treatment is extended to include simultaneous reactions, such as alloy deposition, and to compare the calorimetric measurement of polarization with the more conventional methods.—EL. 19455

3.8.2, 6.3.11

Electrochemical Behavior of Iridium Equilibrium Diagram Voltage Versus pH of the System Ir-H_2O at 25 C. (In French.) J. Van Muylder and M. Pourbaix. Centre Belge d'Etude de la Corrosion, Rapport Technique No. 62,

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March, 1958, 9 pp. Available from Cebelcor, 21 rue des Drapiers, Brussels, Belgium.

Iridium and different iridium compounds in the solid or dissolved state were studied. Free enthalpies. The stability and corrosion of iridium; formation of iridium oxides. 2 plates.—BTR. 19586

3.8.2, 3.8.3, 6.4.4

Electrochemical Behavior of Magnesium: Equilibrium Voltage/pH Diagrams of the System Mg-H_2O, Mg-CO_2-H_2O and Mg-H_2PO_4-H_2O at 25 C. (In French.) J. Van Muylder and M. Pourbaix. Proc. Internat. Cttee. Electrochem. Thermodynamics and Kinetics, Madrid, 1956, **1958,** 218-237. Available from Butterworths Sci. Publications, 88 Kingsway, London WC 2, England.

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The diagrams are established on the basis of free-enthalpy values indicated by Latimer ("Oxidation Potentials", New York, 1951). Theoretical corrosion, immunity, and passivation data for Mg, obtained from the curve for Mg-H_2O, agree with observations, and it is shown that the presence of the carbonate or bicarbonate increases the passivation region. The diagram for Mg is applied to use of the metal as a reactive anode for cathodic protection of Fe. 38 references.—MA. 19553

3.8.2, 6.3.11

Electrochemical Behavior of Rhodium: Potential/pH Diagrams for the Rhodium-Water System at 25 C. (In French.) J. van Muylder and M. Pourbaix. Centre Belge Etude Corrosion, Rapport techn., No. 59, 1-11, 1958. Chem. Absts., **52,** No. 21, 18012 (1958) Nov. 10.

By use of known methods and conventions together with available thermodynamic data, equations are formulated and presented as potential/pH diagrams to summarize the electrochemical behavior of Rh in water at 25 C. Other diagrams are constructed which show the theoretical conditions for corrosion, passivity and immunity to corrosion in the presence and absence of chloride ions. The following standard free-energies of formation are calculated: Rh^+ 14, Rh^{2+} 28, RhO_4^{2-} —15, and RhO_2 (solid) —15 kcal/mole.—MA. 19551

5. PREVENTIVE MEASURES

5.3 Metallic Coatings

5.3.2

Aluminum Coating of Steel Wire. (In German.) H. Krautmacher. Stahl u. Eisen, **79,** 1432-1437 (1959) Oct. 1

Review of plating processes. Influence of bath temperature, carbon content, tensile stress and weight of coated material. With aluminum coatings better corrosion resistance is achieved as compared with zinc coatings. Microstructures of corrosion resistance and structural changes occurring in the heat treatment of aluminum coated wire at 538-650 C for 1000 hr. 32 references.—RML. 19262

5.3.2, 6.3.9, 3.5.9

Coated Molybdenum Withstands 1800 F (980 C). Materials in Design Engineering, **50,** No. 1, 154-158 (1959) July.

A four-layer oxidation-resistant coating for molybdenum turbine buckets has been developed. It consists of 1) a chromium electroplate to give a diffusion-type bond, 2) a nickel electroplate to improve ductility, 3) a fused nickel-silicon-boron coating as a bonding layer for Nichrome cladding, and 4) a 0.006-in. (0.15 mm) brazed layer of Nichrome, hard-surfaced with a chromium-tungsten-cobalt-boron alloy as a final cladding. 19315

5.3.4

Corrosion Protection of Steel Structures in Water by Means of Flame-Sprayed Zinc Coatings. (In German.) Zbigniew Kowalski. Werkstoffe u. Korrosion, **10,** No. 6, 357-363 (1959).

A Polish-made metal-wire-spray pistol is described. Lists of large zinc sprayed Polish installations—dams, railway bridges, etc.—are given. The total cost of zinc-spraying is shown to be less than painting over a 15-year period. 23 references.—MA. 19272

5.3.2, 2.2.5, 2.1.2

Some Aspects of the Corrosion of Decorative Coatings. F. A. Lowenheim and W. H. Rowan. Paper before Am. Electroplaters' Soc., Golden Jubilee Conv., Detroit, June 15-19, 1959. Tech. Proc. Am. Electroplaters' Soc., **46,** 205-210; disc., 379 (1959).

Through both brief analysis of exposure programs of ASTM Committee B-8 and report of a statistical experiment, the value of chromium coatings heavier than conventional 0.01 mil is emphasized. Statistical means whereby many variables can be screened in preliminary fashion while still requiring preparation of minimum number of panels, is presented for consideration. Advantages to be gained by considering 12 tin-bronze instead of copper as undercoat for nickel/chromium, are pointed out. Excellent corrosion resistance of tin-nickel alloy deposit is re-emphasized, and it is shown that it is possible to plate adherent layer of chromium over it. Tables summarize data for exposures at Kure Beach, Newark, Chicago and Pittsburgh; also for CASS tests. 7 references.—INCO. 19293

5.3.4, 8.8.3

Tin in Electroplating. Robert M. MacIntosh. Plating, **46,** No. 6, 617-620 (1959).

MacIntosh describes some typical electrotinning lines employing both the acid and the alkaline processes. Acid solutions are corrosive, but a higher current density may be used than is possible with the non-corrosive stannate bath; deposition from acid solutions requires only half the current needed with stannate. Plant operation is described; tinplate does not cause galvanic corrosion when in contact with a wide variety of other materials. Immersion tinning in stannate solutions is used for coating aluminum alloy pistons to impart improved performance during running-in. Tin alloy plating is briefly discussed.—MA. 19309

5.3.2, 3.5.9

Study of Aluminium-Coated Steel. Pt. X. Behaviour of Aluminium Layer on Heating and Its Influence on Oxidation-Resistance. (In Japanese.) Takuro Saga and Omi Miyakawa. J. Japan Inst. Metals (Nippon Kinzoku Gakkai-Si), **22,** No. 4, 177-180 (1958).

The effect of varying the heating rate (v) was studied. At temperatures slightly below the m.p. of Al, layers thicker than~20 μ tend to flake. At v of~15 C./min. or over from~500 C. to the m.p., the Al layer diffuses uniformly and produces a smooth alloy layer~ 70% of the thickness of the Al. At lower v layers thicker than~30 μ do not confer satisfactory oxidation-resistance, and v<~4° C./min. cause flaking instead of diffusion.—MA 19505

5.3.4

Developments in Decorative Plating. C. H. Sample. Plating, **45,** No. 7, 721-727 (1958) July.

This general paper on chromium plating begins with a short historical section and continues by describing recent developments. Among these are the use of buffed dull nickel undercoats; thick bright nickel undercoats and double layers of nickel as undercoats, which are said to have good resistance to corrosion in marine and rural conditions. 8 figures, 1 table. —ZDA. 19494

5.3.4
The Influence of Aluminum, Lead and Iron on the Structure and Properties of Galvanized Coatings. J. J. Sebisty and J. O. Edwards. Dept. of Mines and Technical Surveys, Ottawa, Canada, Mines Branch Research Report No. R5, March, 1958, 47 pp.

Influence of aluminum and lead additions in iron-saturated baths on the structure and properties of galvanized coating prepared by dry galvanizing technique. Different levels of aluminum and lead, and ranges of bath temperature and immersion time were studied using two grades of sheet steel. Statistical evaluation indicated that immersion time and aluminum content had most significant effect on coating rate, steel rate loss, iron content and alloy growth in coating and in adherence of coatings. Lead content was most significant variable affecting surface appearance of coating. Accelerated corrosion tests suggest aluminum, and to a lesser degree lead, had significant effect on promoting "white rusting" of coatings. 9 references.—MR. 19483

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.1, 3.7.3, 8.8.5
Iron, Carbon Steel and Alloy Steel. R. W. Vanderbeck and E. H. Phelps. United States Steel Corp. Ind. Eng. Chem., **51**, 1178-1184 (1959) Sept.

New production methods and alloying techniques for increasing corrosion resistance in carbon and low-alloy steels and iron alloys are presented. Welding processes and mechanical properties of these alloys are given.—NSA. 19550

6.2.5, 3.2.2
Resistance of Various Steels to Corrosion-Pitting. (In Russian.) M. G. Timerbulatov and G. I. Babushkina. Metalloved. i Termicheskaya Obrabotka Metallov (Metal Sci. and Heat Treatment of Metals), No. 8, 5-12 (1959) August. English Translation of Journal Available from Acta Metallurgica, 122 E. 55th St., New York 22, N. Y.

Results of various types of heat-treatments and plastic deformations of stainless chromium steel and chromium nickel austenite steel show that stainless chromium steel (treated for high strength) exhibits better resistance to corrosion pitting than chromium nickel steel.—NSA. 19562

6.2.2, 3.5.9
Kinetic Study of the Oxidation of Iron at High Temperatures and Under Low Oxygen Pressures. (In French.) Pierre Belin. Corrosion et Anti-Corrosion, **7**, 384-392 (1959) Nov.

Oxidation of Arco and Puron iron at oxygen pressures between 1 and 20 mm mercury and from 800 to 1000 C.—RML. 19688

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.11, 3.7.3
Changes in the Surface Colour of 18-Carat Gold Alloys. G. Rey-Coquais. Chim. et Ind., **80**, No. 1, 11-13 (1958).

Yellowing or "greening" of gold alloys is mainly due to the action of air during successive annealings, converting Cu to CuO which can be dissolved in sulfuric acid. A process of heat-treatment to produce surface diffusion and regenerate the alloy on the surface is considered to be the most satisfactory method of correcting this effect.—MA. 19443

6.3.11, 5.3.2, 4.6.1, 8.4.5
Alternate Control Rod Materials Silver-Base Alloys. Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., WAPD-PWR-PMM-2760, 1958, 11 pp. Available from Office of Technical Services, Washington, D. C.

Nickel plating of Ag-In-Cd alloy was investigated, emphasizing oxygen corrosion prevention of the alloy in high-temperature water. Results are illustrated in macro- and microphotographs. In addition, mechanical properties of the plated specimens are discussed and presented graphically.—NSA. 19600

6.3.10, 6.3.4, 6.2.2
High Alloys to Combat Corrosion. Edward D. Weisert. Product Engineering (Design Digest), **29**, B16-B17 (1958) Sept.

Composition, corrosion resistance of nickel-molybdenum, nickel-molybdenum-chromium, nickel-chromium-iron-molybdenum, cobalt-chromium-tungsten-nickel, cobalt-chromium-tungsten-carbon, iron-silicon, iron-silicon-molybdenum, nickel-silicon alloys.—MR. 19584

6.3.20, 6.2.5, 4.3.3, 4.3.2, 8.4.5
Corrosion of Zr-2 and 304 Stainless Steel Following the Turco-4501 Decontamination Process. A. P. Larrick and R. J. Lobsinger. General Electric Co. Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-59708, April 20, 1959, 17 pp. Available from Office of Technical Services, Washington, D. C.

Investigation at HAPO showed that a proprietary commercial process is one of the more effective methods of decontaminating reactor components exposed to high temperature water. This process consists of a highly alkaline film conditioning bath, a highly alkaline oxidizing bath, and a nitric acid passivation bath. It will remove over 95 percent of the contamination with relatively low metal losses. The uniform corrosion losses due to the solutions for sensitized and nonsensitized 304 stainless steel are 0.008 and 0.003 mils, respectively, for exposure times of 1 hr. in each of the first two solutions and ½ hr. in the third solution. Zircaloy-2 and Zircaloy-3b are not attacked by these solutions. No evidences of crevice corrosion or caustic cracking due to the decontaminating solutions were found. A mild intergranular attack was found on sensitized 304 stainless steel. The presence of hydrogen during a special decontamination resulted in large penetrations to Zr-2 and induced breakaway corrosion upon subsequent exposure to pH 4.5, 300 C water. (auth)—NSA. 19285

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6.3.20, 8.4.5

The Effect of Reactor Atmospheres on Zirconium and Zirconium Alloys. R. G. Wheeler. General Electric Co., Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-55958, May 6, 1958, 13 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Zirconium, Zircaloy-2 and Zircaloy-3b specimens were exposed to a 50 vol. percent helium-50 vol. percent carbon dioxide reactor atmosphere at a weighted average temperature of 430 C for a total of 886 days. Either the irradiation, or some constituent in the gas, appears to reduce the rate of reaction above 450 C primarily by delaying the inception of break-away corrosion. Any initial strength advantage in the materials tested obtained by cold work would soon be lost at temperatures above 400 C because the cold worked specimens were fully annealed by their exposure. The specimens suffered no significant change in ductility or mechanical strength other than that attributable to annealing. (auth)—NSA. 19581

7. EQUIPMENT

7.4 Heat Exchangers

7.4.1, 6.2.4, 5.4.2

Further Corrosion Tests on Materials in Regenerative Air Preheaters. J. F. Barkley, H. Karlsson and C. F. Stark. U. S. Dept. Interior, Bureau of Mines Report of Investigations No. 5471, 1959, 28 pp.

Field tests were made on rate of corrosion of 30 materials used in air preheaters under regular operating conditions, and buildup of deposits was observed. Twenty-three materials were tested with coal as fuel on an underfed stoker and 7 with oil, including a short period with pulverized coal as fuel. Plant equipment is described, and pertinent plant operating data are tabulated. Uncoated metals tested included Cor-Ten (.45 Ni), Otiscoloy, Jalten, Mayari-R (0.28 Ni), NAX (CSX) and Yoloy (HSX) (0.56 Ni) steels, Type 321, a high-strength steel (0.92 Ni); wrought iron; and Al alodized 3003-H14. Majority of coated or plated specimens were of Cor-Ten, with Al, Pyrex glass, and open hearth steel comprising remainder of specimens. Coatings were Al, silicones, enamels, C, and chemoxide. Corrosion rates of Cor-Ten and Mayari-R steel continued to show little difference at generating station using principally oil. Type 321 showed a much higher corrosion rate than Cor-Ten. No coatings resisted corrosion satisfactorily except acid-resisting enamels, XR623A Ferro, Barrows and Erie. These coatings were not attacked, but imperfections in their application resulted in destruction of metal underneath. Properly applied, one coat served as well as two. Descriptions and photos of typical deposits are included. Graphs show percentage loss in weight of test plates relative to that of standard Cor-Ten plate material. Photos, diagrams.—INCO. 19707

7.4.1, 6.4.2, 8.4.5, 4.6.1

Secondary-Side Water Treatment for Corrosion Control in Aluminum Heat Exchangers: Practices and Results at the Oak Ridge Research Reactor. P. D. Neumann. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-59-8-50, August 12, 1959, 19 pp. Available from Office of Technical Services, Washington, D. C.

Standard water treatment practices have proven adequate for scale and corrosion control on the secondary side of the ORR pool-cooling heat exchanger. Corrosion rates measured on specimens exposed to secondary water showed maximum corrosion rates of approximately 1 mpy during the first exposure period and these rates decreased during subsequent exposure. Examination of the heat exchanger tube bundle after 6 months and 13 months of operation showed only minor film formation and very little evidence of corrosion. (auth)—NSA. 19351

7.4.2, 6.3.6, 8.4.5, 3.2.2

Corrosion of Copper in Open Recirculating Water Systems. J. L. Powell. Union Carbide Nuclear Co. Ind. and Eng. Chem., **51,** No. 3, 75A-76A (1959) March.

Case history on problem of corrosion of copper condenser tubes used in gaseous diffusion process for separation of uranium isotopes at AEC plant near Paducah, Kentucky. Extensive cooling facilities are required capable of removing several billion B.t.u. per hour from a Freon coolant at relatively low temperature. Cooling water passes through tube side of condensers while Freon vapors condense on shell side. Treatment of systems for prevention of corrosion and scaling is difficult because condenser tubes are pure copper, while supply headers and associated piping are wrought steel. Pitting of tubes was caused by a combination of 2 independent conditions—presence of copper oxide deposits on tubes when purchased and their use with a cooling water containing ferrocyanide. Corrosion was not affected by low water velocities nor elevated return water temperature. Use of a chromate-polyphosphate water treatment, immediately after discovery of tube failures, satisfactorily arrested accelerated attack.—INCO. 19417

7.4.1, 5.2.1

Cathodic Protection of Heat Exchangers. C. Plumpton and C. Wilson. Univ. of London. Brit. Chem. Eng., **4,** 200-205 (1959) April.

The basic types of heat exchangers are discussed, and the main forms of corrosion to which they may be subjected are considered. Anti-corrosive measures used to date are reviewed and an account is given of the mathematical theory of cathodic protection. Consideration is also given to the engineering problems peculiar to cathodic protection. —NSA. 19403

7.4.2, 5.9.3, 5.9.2, 5.8.1

Reduce Cooling System Corrosion. C. T. Palen. Shell Oil Co. Petroleum Refiner, **38,** No. 5, 239-242 (1959) May.

Oily films left on new steels condenser and cooling tubes as result of fabrication and assembly operation interfere with uniform adsorption of inhibitor on tube surfaces when heat exchanger is first placed in service. Tests comparing corrosion and fouling of untreated steel tubes and tubes pretreated with hot detergent soak, sandblasting and cold inhibitor soak establish that precleaning of new steel condensers and coolers is essential. Other factors considered are reaction of chromate inhibitor with soluble redwood leach (from cooling tower lumber), accumulation of wood fiber and sawdust in tubes under stagnant conditions and rapid depletion of inhibitor by new steel tubes while inhibiting film is being formed. New procedure for pretreatment and initial operation of cooling system eliminates these problems. Graphs.—INCO. 19367

7.5 Containers

7.5.2, 6.4.2, 8.3.3

Aluminium Milk Cans. Pt. I. O. J. Bruun. Dairy Eng., **76,** No. 1, 5-8 (1959).

Pros and cons of aluminum and steel cans with regard to hygiene, strength, corrosion and cost are discussed. A brief outline of the manufacturing process of aluminum cans and the machines involved is given with illustrations.—MA. 18248

7.5.2, 5.4.5, 8.3.5

Protective Lacquers for Tinplate. H. Buchholz. Ind. Conserve, **34,** No. 1, 17-19 (1959).

Electro-tinplate containers, and particularly cans for preserved foods, require a suitable protective lacquer. After some considerations on the possibilities of lacquering according to the present state of scientific development, the author points out the advantages offered by epoxy resins, with special reference to the protection of the can interior.—RPI. 19696

7.5.2, 8.3.5, 6.3.14

Corrosion of Tin Plate Containers in the Canned Food Industry. (In French.) H. Cheftel. Corrosion et Anticorrosion, **7,** 125-133 (1959) April.

Influence of type of steel, presence of cathodic depolarizing agents, storage temperature. Evolution of potentials of tin and steel in couples in which tin plays role of anode. 34 references.—RML. 19058

8. INDUSTRIES

8.1 Group 1

8.1.1, 5.4.5

Corrosion Protection for Fans. A. N. Rogers. Westinghouse Elec. Corp. Air Conditioning, Heating & Ventilating, **56,** No. 5, 57-62 (1959) May.

Application guide for corrosive resistant, gas tight and spark resisting fans. Two basic methods of obtaining corrosion protection in air handling products are use of corrosion resistant metals in construction of fan, and use of a protective coating on exposed surfaces of a standard steel fan. Extensive table serves as a guide to corrosion resisting characteristics of various materials, linings and coatings and has been set up to show type of corrosion service material or coating is capable of handling. Metals listed include standard steel, Types 304 and 316, Monel, brass or bronze and aluminum. Coating materials include natural and synthetic rubbers, neoprene, phenolics, epoxys, vinyls, bitumins, and chlorinated rubber paint. Criteria for selection of protection are considered. —INCO. 18513

8.1.4, 7.4.1, 6.2.2, 4.3.2, 4.2.3

Twenty-Two Years of Experience with Sewage Gas Engines. W. A. Sperry. Public Works, **90,** No. 4, 101-103, 194 (1959) April.

Following brief review of history of installation of gas engines in sewage treatment plants in U. S., installation of

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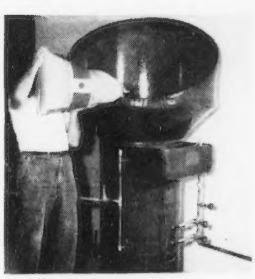

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engines at Aurora, Illinois, Sanitary District plant in 1936 is described in detail, with operating record to date. Most troublesome and expensive problem revolved around exhaust heat exchanger. Problem of corrosion in iron exchanger tubes is associated with condensation and hydrogen sulfide content of gas used. Tubes always failed at those points where exhaust temperature was coolest, i.e., near lower ends of tubes. Corrosion would be negligible if condensation could be avoided, which would be the case where exchanger temperatures could be held at 250-300 F range. While many plants must make use of scrubbers to reduce hydrogen sulfide, Aurora experience is that plants with hydrogen sulfide of 25 grains per 100 cu ft or less do not require scrubbers. Since hydrogen sulfide severely attacks copper and brass only iron pipe should be used. As iron pipe periodically tends to accumulate iron sulfide as tubercles in masses, pipe needs occasional hammering, to loosen these masses, and flushing. Small diameter pipe should not be used. Illustrations.—INCO. 19411

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8.2 Group 2

8.2.2, 1.2.5

Solving a Corrosion Mystery. Product Eng., **29**, No. 15, 21-22 (1958) April 14.

Type of corrosion never before encountered which induced piston seizure in control system, wrecked 60 MW turbo alternator at Uskmouth power station. Disaster was initiated by accidental tripping of main exciter. Steam valves remained open for period of 13 seconds after load ejection and caused turbine overspeed condition of 70 percent. Low-pressure turbine, its shaft and generator rotor disintegrated. Dilute solution of sodium chloride present in oil system as result of sea water leakage attacked piping and caused deposition of finely divided pure magnetite on piston, cylinders and valves in control mechanisms. As result of reciprocating motion, these particles were compacted into an extremely hard interference film.—INCO. 16587

8.2.2, 7.6.1, 3.2.2, 5.7.1, 5.8.1

Treating Different Types of Corrosion. G. G. Sindery. Modern Power and Eng., **53**, No. 9, 117-119, 140, 160-161 (1959) Sept.

Corrosion of power plant and process equipment is considered under following headings: high-pressure boiler plant and associated feed system; low-pressure boilers; steam-heated appliances and condensate return system; cooling systems; high- and low-pressure hot-water heating systems; and cold water lines. Types of corrosion occurring in each part of system are discussed, along with causes, contributing factors, methods of treatment, and preventive measures. Among topics considered are pitting, corrosion embrittlement, attack by CO_2 and O_2, H_2 evolution type of corrosion and blanket corrosion. Techniques for combatting corrosion include addition of caustic soda for pH adjustment; conditioning with Na sulfite, Na nitrite or selected tannings to ensure absence of O_2 in boiler water; deaeration; pretreatments such as zeolite base-exchange process; and inhibition by amines, polyphosphates and other inhibitors; certain water treatment methods actually increase corrosiveness of water. Corrosion can be greatly reduced by correct selection of pretreatment method and can be eliminated by choice of a conditioning treatment suited to service conditions. Illustrations.—INCO. 19461

8.8 Group 8

8.8.1, 2.3.8, 1.2.2

Preparation of Acid Deficient Aluminum Nitrate by Electrodialysis. E. J. Parsi. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-54-4-131, April 14, 1954 (Declassified Feb. 14, 1957), 14 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

A continuous method for the production of acid deficient aluminum nitrate was developed in a semi-pilot scale electrodialysis unit. Using this method a clear solution of 90 percent monobasic 0.6*M* aluminum nitrate has been produced at a rate of 0.37 liters/hr. A by-product 0.29*N* nitric acid containing less than 40 ppm aluminum was also produced at a rate of 0.57 liters/hr. From the data obtained in this run, a preliminary cost estimate for the continuous production of acid deficient aluminum nitrate 0.6*M* in aluminum and 0.44 acid deficient was made. It was based on the requirements of the Thorex pilot plant of approximately 24 liters/hr. The cost is largely dependent on the rate of corrosion of the anode and on the labor required. However, on scaling up labor costs will be reduced, but the cost of the anode replacement will not be changed. The cost of a unit to satisfy the needs of the Thorex pilot plant is of the order of $500 exclusive of anode costs. Adding up the cost of auxiliary equipment and installation, the total cost of the unit is approximately $3700. It will cost $3500 to use 0.001 in. platinum foils as anodes. At this low scale of production and assuming a platinum corrosion rate of 0.05 mg/a-hr., the cost per lb. of aluminum is approximately 64¢ of which 37¢ is labor and 10¢ is platinum loss. To this must be added $1.49/lb of aluminum in the aluminum nitrate feed. Scaling up by a factor of 20 over the Thorex pilot plant unit, the installed cost of the unit will be of the order of $43,500 and the investment in platinum about $70,000. Using the same assumption as in the smaller scale unit, the cost per lb. of aluminum produced is approximately 35¢, of which 11¢ is labor and 10¢ is platinum loss. Again the cost of aluminum in the feed must be added to the above figure. All the equipment was amortized at 16 percent per annum, except for the ion exchange membranes and gaskets, for which a conservative 200 percent was used. This method is very attractive, but its economic feasibility hinges heavily on the rate of corrosion of platinum as an anode in nitric acid or in the development of a suitable substitute anode. (auth)—NSA. 17982

8.8.5, 6.3.6

Corrosion Resistance of Non-Ferrous Casting. A. H. Rollins. Corrosion Technology, **6**, No. 9, 259-262 (1959) Sept.

Special nature of cast materials and its significance in relation to corrosion resistance is considered briefly. Blowholes, shrinkage cavities and gas porosity adjoining surface of casting lead to pitting and perforation. Conditions for deposit attack can be simulated by presence of non-metallic inclusions in surface, while chemical inhomogeneity (due to segregation, galvanic effects) may lead to galvanic effects. In considering corrosion behavior of Cu-Sn and Cu-Al alloys, mention is made of: beneficial effects of adding small amounts of Ni to gunmetals; the special applications of alloys containing 20-50 Ni, 6-8 Sn, 1-2 Zn, remainder Cu; and superior properties of Ni-containing Al bronzes. Ni base castings (including Monel) are commented on, as are Al-base and Mg-base alloy castings.—INCO. 19407

8.8.5, 6.3.10, 6.3.4

The Effects of Melting and Casting Procedures on the Elevated Temperature Properties of Nickel and Cobalt-

Base Alloys. M. J. Stutzman and J. W. Cunningham. Westinghouse Elec. Corp. Trans. Am. Inst. Mining and Met. Engrs. (Met. Soc.), **215,** No. 4, 637-646 (1959) August.

Stellite 31 and He 1049 (cobalt-base alloys) were each melted and cast in air and melted in vacuum and cast under argon. Udimet 500 (nickel-base) was melted and cast in vacuum with and without additions of boron and zirconium. Guy Alloy (nickel-base) was melted and cast in vacuum and argon atmosphere. All casting was investment casting. Tensile tests were run at room temperature, 1200, 1500 and 1700 F. Stress-rupture tests were run at 1250, 1500, 1600, 1700 and 1800 F. Oxidation resistance was determined as weight gain following constant temperature exposures to air at 2000 F, and intermittent exposures to air at room temperature and 2000 F. Results showed that improvement in one property by vacuum melting resulted in decrease in another. Ductility of Stellite 31 was increased by vacuum melting but oxidation resistance was decreased. Stress-rupture elongation and constant-temperature oxidation of He 1049 were improved by melting in vacuum and under argon, but intermittent oxidation resistance was greater for material melted and cast in air. Oxidation resistance of Guy Alloy was definitely improved by melting and casting in vacuum. Additions of zirconium and boron to vacuum-melted Udimet 500 gave increased stress-rupture elongation at all test temperatures and tensile elongation at 1700 F but decreased oxidation resistance appreciably. Tables, graphs, photomicrographs.—INCO. 19516

8.9 Group 9

8.9.4, 6.4.2, 4.3.6

The Pechiney Railway Cars for the Transport of Salt. (In French.) Pierre Bandet. Rev. Aluminium, **35,** No. 251, 189-192 (1958) Feb.

Engineering details of the railway hopper cars built for the transport of marine salt from the seashore installations to the processing plant operated by Pechiney, are given. These large capacity vehicles are characterized by the exclusive use of light alloys, aluminum-3 percent magnesium, aluminum-5 percent magnesium and aluminum-silicon-magnesium alloys, for the construction of the bodies and frames. The effective volume capacity is 2,295 cu. ft.; the weight, when loaded, is 88 tons, tare weight is 17.6 tons. The total amount of light alloys used in each of these cars amounts to 5.9 tons. The reason for having chosen aluminum as a construction material was that this particular company extracting salt from seawater was already using aluminum alloy equipment for a number of years and, thus, they had direct experience concerning the resistance to salt and seawater of alloys of this kind.—ALL. 19659

8.9.4

Chemistry and the Railways. F. Fancutt. Chemistry and Industry, No. 6, 172-180 (1959).

An account of the varied interest in chemical matters taken by British Railways. After a brief account of the Chemical Services establishment, the subjects discussed are lubrication, paint materials requirements and test procedures, cleaning of rolling stock and motive power units, corrosion, new structural materials, e.g., polyester glass laminates, electrical requirements and assessment of fuel, analysis of effluent, carriage of dangerous goods, pest infestation, protection of building materials, e.g., brick, control of weeds and mould growth and wood preservation.—RPI. 19752

8.10 Group 10

8.10.2, 5.2.3, 5.4.2

Corrosion Control at Grand Isle. A. E. Hiller. Freeport Sulphur Co. Petroleum Engr., **31,** No. 7, B41-B42, B44-B45 (1959) July.

Freeport Sulphur is preparing corrosion protection of 15,000 tons of steel in a mile-long tower and bridge structure at world's first offshore sulfur mining plant off the coast of Louisiana. Three different corrosion environments which must be guarded against are totally submerged zone, splash zone which lies immediately above, and salt-air zone. Most widely accepted measures for protection of splash zone (most susceptible to corrosion and most difficult to protect from corrosion) are use of additional steel, in form of "double-plate" or an increase in thickness of structural member in splash zone; or use of Monel sheathing. Freeport has chosen to install a section of rolled steel 0.875-in. thick in permanent structures and 0.6875-in. thick in temporary structures. Corrosion in submerged area will be controlled by cathodic protection under an impressed current system, which is described. Platform superstructure is protected from corrosion by inorganic zinc silicate coating. Illustrations.—INCO. 19221

8.10.2, 6.3.17

Recovery of Uranium from Residues Produced in Hydrochlorination of Nuclear Fuel Alloys. T. A. Gens. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-59-4-9, April 10, 1959, 9 pp. Available from Office of Technical Services, Washington, D. C.

Chlorination at 550 to 600 C of Zircex residues with carbon tetrachloride resulted in greater than 99.99 percent recovery of the uranium. Both the hydrochlorination residue and the solids which remain after leaching the hydrochlorination residue with nitric acid were chlorinated with similar results. By this technique, loss of 1 to 6 percent of the uranium to the nitric acid insoluble residue, which occurs in simple hydrochlorination and dissolution of STR fuel, is avoided. Other advantages include reduced corrosion and the elimination of possible explosions between U-Zr alloys and nitric acid. A modified flowsheet is proposed. (auth)—NSA 19776

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A. O. Smith Corp., Milwaukee, Wis.

J. E. RENCH 1960-63
Napko Corporation, Houston, Texas

J. S. DORSEY 1960-63
Southern California Gas Co., Los Angeles, Cal.

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Dowell Incorporated, Tulsa, Okla.

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E. H. TANDY . . . . . (Western) 1958-61
Standard Oil Co. of California, El Segundo, Cal.

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OFFICIAL MONTHLY PUBLICATION

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An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 16 December, 1960 No. 12

Impressed Current Anodes for Cathodic Protection*

By WALTER P. NOSER

Abstract

Development and use of impressed current anodes for cathodic protection of underground structures is traced from early beginning to present time. Data for calculating anode resistance to earth is presented. Recommendations are made for installing anodes for various soil conditions. Advantages are given for deep ground beds in high resistivity soil and in urban areas. Use of lead alloy and platinum anodes for underwater use is mentioned. 5.2.3

Introduction

ANODES FOR cathodic protection are either of the galvanic type which provide their own direct current or impressed current type which require an external source of direct current. The external direct current for impressed current anodes is usually provided by rectifiers but it can be provided by batteries, windmill or gas engine generators, or other sources. Figure 1 shows the direction of current in a typical system. The negative side of the current source drains the current from the structure to be protected, and the positive side impresses the current on an expendable anode. The circuit is completed by the current flowing from the impressed current anode through the soil or other electrolyte to the protected structure.

This paper traces the development of the impressed current anode from its early beginning to the present time. Emphasis is placed on the use of anodes for cathodic protection of underground structures.

Early Patents and Tests

Herman Geppert of Karlsruhe, Germany, obtained Patent 989,596 in 1911 which describes a "Method of Protecting Articles from Earth Currents." While the patent was obtained primarily as a protection against stray currents it is worded broadly enough to cover cathodic protection by means of impressed current anodes where no stray current exists. Geppert's description of the method states, "The article to be protected is connected to the negative pole of any convenient source of electricity (cells, accumulators, dynamos) while at the same time anodes sunk into the earth in suitable positions are connected to the positive pole of the same source of electricity."[1]

Whether or not the men making early experiments with impressed current anodes for cathodic protection knew of this patent can only be conjectured.

Robert J. Kuhn in a report to the first United States Bureau of Standards Corrosion Conference in 1928 described galvanic currents that circulate around a corroding pipe, discharging from the pipe at the corroding points and collecting on other areas. He suggested that corrosion could be prevented by reversing the direction of the discharging current.

Kuhn applied this idea in protecting a welded steel high pressure gas piping system in New Orleans. Electric street railway drainage current was applied to the gas system to prevent both electrolysis and soil corrosion. A short time later rectifiers were installed in two locations where the effect of railway currents was insufficient.

On the West Coast, Otto Knopp and W. R. Schneider were experimenting with cathodic protection installations in 1930.[2]

Early in 1931, Starr Thayer made some tests on a four mile 6 inch coated gas line near Sugar Land, Texas. The anode or ground bed was made of junk pipe placed 1200 feet from the pipeline with a bare overhead copper connection between the ground bed and the pipeline. Tests showed that corrosion could be arrested at a reasonable cost of operation.

The following year, Thayer installed a ground bed, somewhat similar to Figure 1, composed of a cluster of 50 lengths of cast iron pipe placed vertically in the ground at a distance of 600 feet from the pipeline. This installation between Baton Rouge and New Orleans, Louisiana, is noteworthy because of the size of the rectifier house. Inside a 6 foot x 8 foot wooden house was a service entrance switch and a multiple tap transformer for stepping down the 110 volt alternating current input to the desired voltage. The low voltage alternating current was rectified to direct current by a bank of 88 copper oxide rectifier stacks, which extended along one wall of the house.[3]

In the period between 1932 and 1934, O. C. Roddey and George I. Rhodes made extensive experiments with anodes of various types, sizes and configurations. Tests made on pipe driven vertically into the ground indicated that better results were obtained from a long line of anodes than from other configurations. When the line of pipe anodes was placed at right angles to the pipeline the earth currents would flow in a direction generally parallel to the pipeline and when they were placed parallel to the pipelines, the earth currents would flow in a direction generally perpendicular to the pipeline.

Experimental work led to the development of the distributed anode system illustrated in Figure 2. Impressed current anodes chosen were coke anodes with hard carbon cores. They were chosen because the weight of coke consumed was estimated to be 4 pounds per ampere year as compared to 20 pounds per ampere year for steel anodes. It was expected that the hard carbon cores would be affected only slightly or not at all by electrolytic action because the current would be conducted to the coke through solid contacts. The electrolytic action would be at the surfaces of the coke particles. Rhodes proposed to replace the coke as it was consumed.

The hard carbon rods were standard arc-furnace electrodes modified as shown in Figure 3. Because of early galvanic corrosion failures between the carbon, copper and soldered connections, it was found necessary to moisture-proof the ends of the rods by impregnating the ends with melted paraffin. A mechanical connection was made between the cable

About the Author

WALTER P. NOSER, senior corrosion engineer with Humble Pipe Line Company, Houston, Texas, has been active in corrosion control work since 1941. He helped in the early organization of NACE and was the first chairman of the NACE Houston Section. He has a BS in electrical engineering from the University of Texas.

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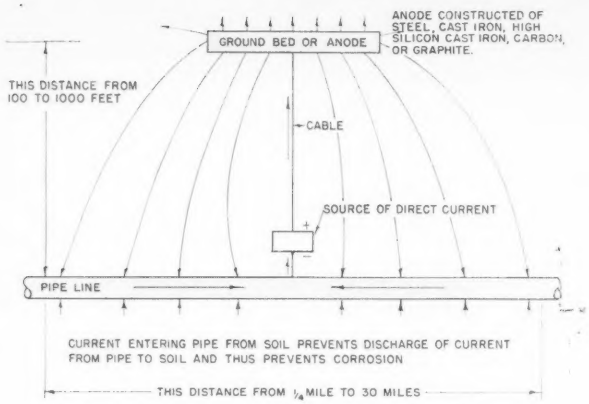

ANODE CONSTRUCTED OF STEEL, CAST IRON, HIGH SILICON CAST IRON, CARBON, OR GRAPHITE.
GROUND BED OR ANODE
THIS DISTANCE FROM 100 TO 1000 FEET
CABLE
SOURCE OF DIRECT CURRENT
PIPE LINE
CURRENT ENTERING PIPE FROM SOIL PREVENTS DISCHARGE OF CURRENT FROM PIPE TO SOIL AND THUS PREVENTS CORROSION
THIS DISTANCE FROM 1/4 MILE TO 30 MILES

Figure 1—Diagram showing application of cathodic protection.

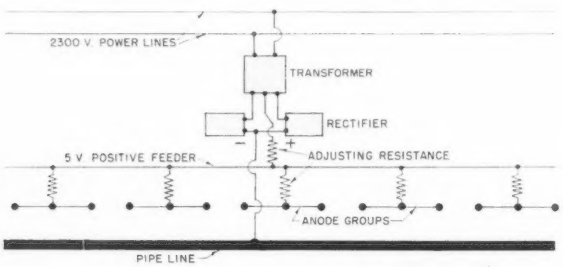


Figure 2—Cathodic protection with distributed anodes.

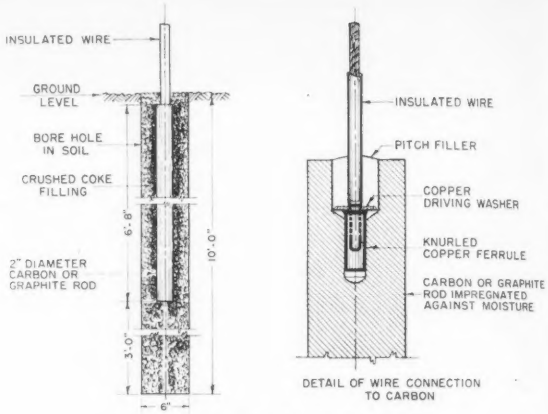


Figure 3—Coke anode for pipe line drainage.

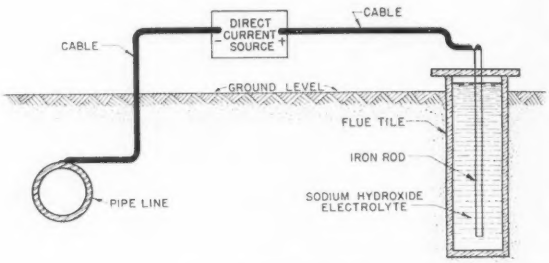


Figure 4—Insoluble anode.

and the anode, and the cable connection was made water-proof with pitch.[4, 5]

An interesting development for an insoluble anode was proposed in 1940 by A. W. McAnneny. His patent for an anode for cathodic protection states, "A metallic electrode is immersed in an electrolyte and a current density is employed such as to set up a state of passivity in the electrode, whereby the metal of the electrode will not go into solution. The electrolyte is held in a container formed of a porous material such as flue tile or china clay which will allow the liquid to "sweat" through and yet be retained without actual leakage. The electrode immersed in the electrolyte or anolyte within the container forms an anodic half cell from which electric current passes through the soil to the buried pipeline comprising the cathode."

Two types of electrodes were proposed: iron in a caustic solution (Figure 4), and lead in a sulfuric acid solution. Both types worked under test but the practical problems of keeping the electrolyte quantity and concentration constant proved to be costly.[6, 7]

Anode Resistance to Earth

Little thought was given to effective engineering design in the early installations of impressed current anodes. The most important consideration was to get as much current into the earth as possible. An anode with a large surface area and a low resistance to earth was required. Thayer accomplished this by placing a number of pipe joints in a large group removed some distance from a pipeline. Others used anodes with relatively large areas and weights such as discarded steel or cast iron pump cases, engine blocks, flywheels or other metal objects. Rhodes used a large number of small anodes placed relatively close to a pipeline.

The anodes were thought of as being analogous to grounding rods used for electrical power plants. Calculations developed by O. S. Peters for grounding rods were used by W. R. Schneider to make a set of curves of resistance to earth for both horizontal and vertical anodes.[8] Derk Holsteyn used similar calculations made by H. B. Dwight to make the curves illustrated in Figure 5.[9] Similar curves based on theoretical and empirical data have been made by others.[10, 11, 12]

All such curves point up the important fact that the anode resistance to earth varies directly as the soil resistivity and inversely as the length and diameter of the anode as shown in curve "A" and "B" of Figure 5.

Table 1 shows the resistance to earth of single vertical anodes of various diameters and lengths in 1000 ohm centimeter resistivity soil. Dimensions shown are total for anodes and carbonaceous backfill. For soil resistivity other than 1000 ohm centimeter, use that value as numerator and 1000 as denominator and multiply by the values shown in Table 1.[13]

When a number of vertical anodes are connected together in a long line the total resistance to earth of the group cannot be calculated according to parallel circuit formula. Additional resistance is introduced by mutual interference between individual anodes by the lengths and diameters of the anodes and by the spacing between them. The parallel resistance value must be multiplied by a correction factor in order to arrive at the total resistance to earth of the group of anodes.

The calculations of anode to earth resistance for a single vertical anode is based on H. B. Dwight's equation shown under Table 1. Knowing this value one can calculate the resistance of a group of anodes placed in a long straight line from the formula:

$$R_t = \frac{R}{n} \times \text{C.F.}$$

Where R_t = anode group resistance to earth in ohms
R = single anode resistance to earth in ohms (From Table 1)
n = number of anodes in group
C.F. = correction factor.

H. B. Dwight gives a formula for a correction factor for a long line of vertical anodes.[14]

$$\text{C.F.} = 1 + \frac{\log_e\left(\text{Cot}\frac{\Theta_2}{2}\right)\left(\text{Cot}\frac{\Theta_3}{2}\right)\ldots\ldots\left(\text{Cot}\frac{\Theta_n}{2}\right)}{\log_e\frac{4L}{a} - 1}$$

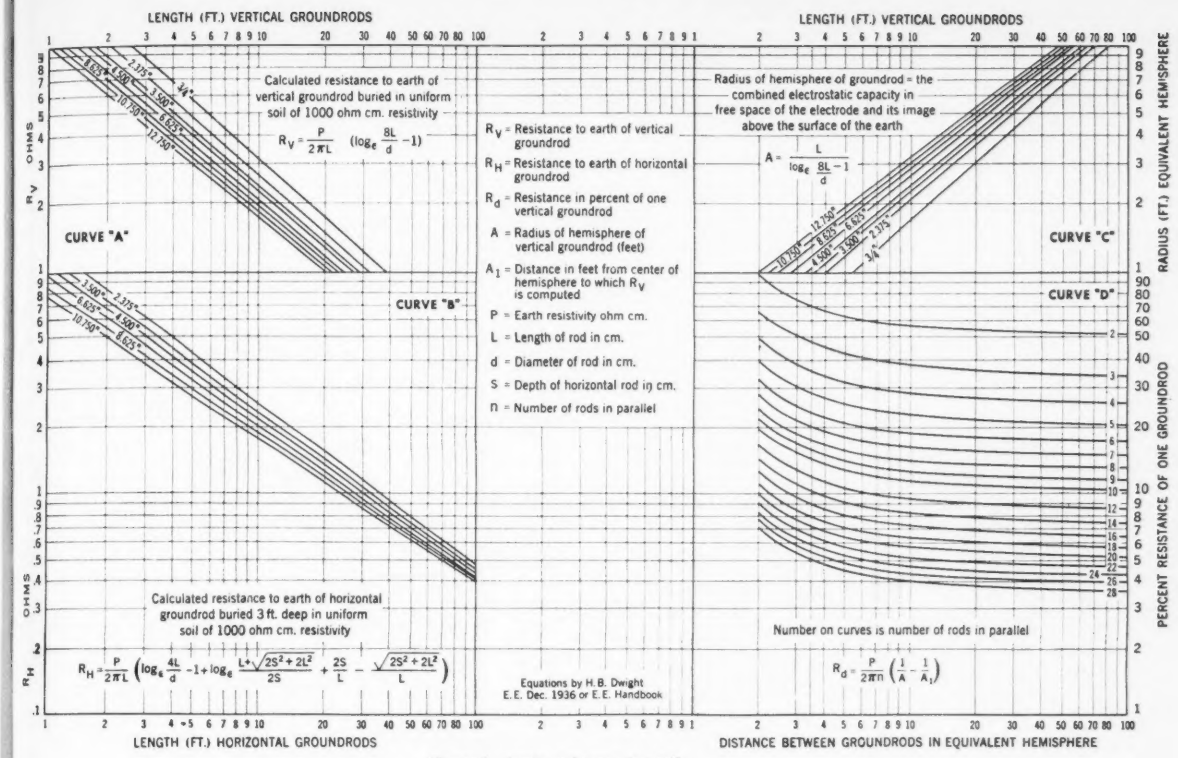

LENGTH (FT.) VERTICAL GROUNDRODS
Calculated resistance to earth of vertical groundrod buried in uniform soil of 1000 ohm cm. resistivity
$R_V = \frac{P}{2\pi L}\left(\log_e \frac{8L}{d} - 1\right)$
CURVE "A"
CURVE "B"
OHMS
R_V
R_H
Calculated resistance to earth of horizontal groundrod buried 3 ft. deep in uniform soil of 1000 ohm cm. resistivity
$R_H = \frac{P}{2\pi L}\left(\log_e \frac{4L}{d} - 1 + \log_e \frac{L+\sqrt{2S^2+2L^2}}{2S} + \frac{2S}{L} - \frac{\sqrt{2S^2+2L^2}}{L}\right)$
LENGTH (FT.) HORIZONTAL GROUNDRODS
R_V = Resistance to earth of vertical groundrod
R_H = Resistance to earth of horizontal groundrod
R_d = Resistance in percent of one vertical groundrod
A = Radius of hemisphere of vertical groundrod (feet)
A_1 = Distance in feet from center of hemisphere to which R_V is computed
P = Earth resistivity ohm cm.
L = Length of rod in cm.
d = Diameter of rod in cm.
S = Depth of horizontal rod in cm.
n = Number of rods in parallel
Equations by H. B. Dwight E.E. Dec. 1936 or E.E. Handbook
LENGTH (FT.) VERTICAL GROUNDRODS
Radius of hemisphere of groundrod = the combined electrostatic capacity in free space of the electrode and its image above the surface of the earth
$A = \frac{L}{\log_e \frac{8L}{d} - 1}$
CURVE "C"
CURVE "D"
Number on curves is number of rods in parallel
$R_d = \frac{P}{2\pi n}\left(\frac{1}{A} - \frac{1}{A_1}\right)$
RADIUS (FT.) EQUIVALENT HEMISPHERE
PERCENT RESISTANCE OF ONE GROUNDROD
DISTANCE BETWEEN GROUNDRODS IN EQUIVALENT HEMISPHERE

Figure 5—Anode resistance to earth.

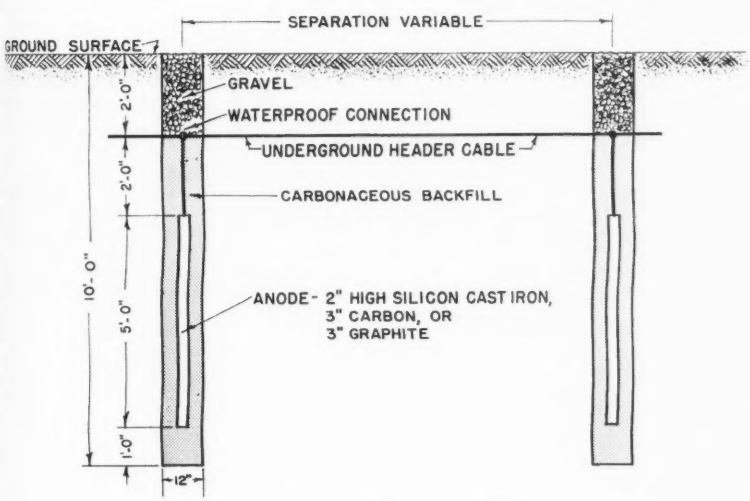


Figure 6—Typical vertical anode installation.

Where $\Theta_n = \text{Arc Cot } \frac{L}{ns}$

L = length of anode in Cm.
s = spacing between anodes in Cm.
n = number of anodes in parallel
a = radius of anodes in Cm.

Frank Dorr, in a report to NACE Technical Unit Committee T-2B furnished information shown in Table 1 and a curve from which the values of Table 2 were read for the specific conditions where

$$L = 243.84 \text{ Cm.} = 8 \text{ feet}$$
$$a = 15.24 \text{ Cm.} = 6 \text{ inches}$$

$$\text{Log}_e \frac{4L}{a} - 1 = 3.0 \qquad (13)$$

The use of Tables 1 and 2 in designing a ground bed will be discussed later.

Most published values of resistance of an anode to earth or of a group of anodes to earth are based on calculations which assume uniform earth resistivity from the surface of the earth to the depth of the anodes. Curves or tables of such values should be used for estimating purposes only. The curves in Figure 5 and the values in Tables 1 and 2 are more accurate for relatively shallow anodes than for deep anodes.

Work of NACE Technical Unit Committee T-2B

NACE Technical Unit Committee T-2B, Anodes for Impressed Current, was formed in 1947 to study the materials which might be used as ground anodes in connection with cathodic protection systems where direct current from an external source is impressed on the anodes.

Committee T-2B initiated study and tests on anode materials such as steel, carbon and graphite and on the study of the materials which might be used as suitable backfill environment for the anodes under test.

In addition to the information included in the initial tests, committee members have made reports on other anode materials such as high silicon cast iron, aluminum, lead, and platinum, on the environment in which the anodes have been tested, and on the methods of installing anodes.[15]

Ground Bed Installation Recommendations

Use has been made of published information, T-2B Committee Reports and Minutes of Meetings and practical experience to formulate the following general conclusions and recommendations for optimum results from relatively shallow impressed current anode installations.

TABLE 1—Resistance to Earth in Ohms of A Single Vertical Anode in 1000 Ohm-cm Soil

Anode Length in Feet	Anode Diameter in Inches							
	3	4	6	8	10	12	14	16
1	12.85	11.34	9.23	7.75	6.59	5.63	4.85	4.40
2	8.25	7.50	6.44	5.69	5.11	4.63	4.22	3.88
3	6.21	5.71	5.00	4.50	4.11	3.79	3.53	3.29
4	5.03	4.66	4.13	3.75	3.46	3.22	3.02	2.84
5	4.26	3.96	3.53	3.23	3.00	2.81	2.65	2.51
6	3.71	3.46	3.10	2.96	2.85	2.50	2.36	2.25
7	3.30	3.08	2.78	2.56	2.39	2.26	2.14	2.04
8	3.00	2.78	2.52	2.33	2.18	2.06	1.96	1.87
9	2.72	2.53	2.32	2.14	2.00	1.91	1.82	1.76
10	2.49	2.34	2.14	1.97	1.82	1.77	1.69	1.64
20	1.43	1.33	1.25	1.17	1.11	1.07	1.03	.985
50	.665	.625	.594	.564	.532	.522	.505	.490
100	.367	.354	.332	.318	.307	.296	.288	.282
150	.260	.250	.236	.226	.218	.212	.207	.202
200	.202	.195	.184	.177	.174	.166	.162	.159

$$R = \frac{\rho}{2\pi L}\left(\text{LOG}_e \frac{4L}{\alpha} - 1\right)$$

R = Resistance to earth of single vertical anode in ohms.
ρ = Soil resistivity in ohm-centimeter.
L = Length of anode in centimeters.
α = Radius of anode in centimeters.
Dimensions are total of anode and backfill.

TABLE 2—Resistance Correction Factor For Vertical Anode Spacings

Number Anodes In Line	SPACING BETWEEN VERTICAL ANODES, IN FEET					
	5	10	15	20	25	30
5	1.64	1.34	1.23	1.17	1.13	1.12
8	1.87	1.45	1.31	1.23	1.18	1.15
10	1.98	1.51	1.34	1.26	1.20	1.17
12	2.07	1.56	1.37	1.28	1.22	1.19
14	2.16	1.60	1.40	1.30	1.24	1.20
16	2.22	1.64	1.42	1.32	1.25	1.21
18	2.28	1.66	1.44	1.34	1.27	1.22
20	2.34	1.69	1.46	1.35	1.28	1.23
24	2.44	1.73	1.49	1.37	1.30	1.24
27	2.50	1.77	1.51	1.39	1.31	1.25
33	2.60	1.82	1.54	1.41	1.33	1.27

$$Rt = \frac{R}{n} \times \text{C.F.}$$

Rt = Anode group resistance to earth in ohms.
R = Single anode resistance to earth in ohms.
n = Number of anodes in group.
C.F. = Correction Factor.
Anode in 12" by 96" backfill column.

1. *Ground Bed Sites*

Ground bed locations should be chosen after a careful soil resistivity survey is made. Ground beds should be placed at the sites of lowest soil resistivity. The topography should be such that natural drainage will provide uniform yearly moisture. The anodes should be installed so that their entire length is buried in permanently moist soil. If only the lower portion of a vertical anode is in permanent moisture, accelerated attack will occur on the lower end and anode life will be shortened considerably.

2. *Anodes Installed Without Backfill*

If anodes are to be installed in fresh or salt water locations or in quicksand, or other locations where placing of auxiliary backfill is impractical, the use of high silicon cast iron anodes can be expected to give long service with low installation cost.[16] The high silicon cast iron alloy with molybdenum is preferred where high chloride environments are encountered or in fresh waters where temperature may be above 125 F. Provisions should be made for venting to atmosphere the gases formed around the anode.

3. *Backfill for Impressed Current Anodes*

A carbonaceous backfill is recommended for impressed current anodes at all locations where it is practical to install a backfill. The backfill will improve the operation of an impressed current anode by:

a. Lowering the anode resistance to earth as compared with anodes in natural soil.

b. Increasing anode life.

c. Allowing greater current capacity per anode. This is especially true for carbon and graphite anodes.

d. Reducing effect of gas blocking.

e. Allowing anode to function more uniformly with less selective attack on anode.

Current output of impressed current anodes is about the same in carbonaceous backfills composed of graphite particles, calcined petroleum coke breeze or coal coke breeze if the resistivity of the compacted backfill material is less than 25 ohm-centimeters. Choice of the material should be made on the basis of delivered cost alone.

The backfill material must be thoroughly compacted about the anode to provide physical contact between individual particles for best performance. Backfill should be graded to number 8 mesh particle size with less than 10 percent dust content.

When backfill is used there is little to choose between carbon, graphite or high silicon cast iron as a material for the anode. Graphite is preferred over carbon except where appreciable quantities of bromides or fluorides might be present at the anode location.

4. *Installation*

It is recommended that anode and backfill be installed in augered holes for vertical installation or in trenches for horizontal installation with a minimum thickness of compacted backfill at least three times the diameter of the anode core in use. Backfill should extend at least one foot above and below vertical anodes and a minimum one foot at each end of horizontally placed anodes. A much greater decrease in anode to earth resistance can be achieved by increasing the length of backfill column rather than increasing the diameter of the column.

Gases formed at the anode can be vented to atmosphere by extending the backfill above the anode to the surface or by placing gravel above the backfill.

The optimum performance from anodes can be achieved if the anodes are installed in soil of uniform electrical resistivity. It is often necessary to install ground beds where the soil structure consists of two or more strata of different electrical resistivities. It is better to install the anode in the lower resistivity strata if possible, although this may require that holes be dug deeper than normal if the lower resistivity strata is covered by a high resistivity strata.

If the low resistivity strata overlays a high resistivity strata, the anode should be placed either vertically or horizontally in the upper strata. Figure 6 shows vertical installation and Figure 7 horizontal installation. This type of installation may be affected greatly by seasonal variation of rainfall. Performance of vertical rods will be normal during wet seasons but the anode can be expected to be attacked on its lower end during dry seasons when the current output is concentrated on that part of the anode. Horizontally placed anodes should be installed near the middle portion of the lower resistivity soil for best all-around performance.[17]

Deep Ground Beds

In some areas, lack of rainfall, absence of low resistivity surface soil, difficulty in getting ground bed right of way and other reasons has led to the installation of relatively deep ground beds. The distinction between "shallow" and "deep" ground beds is not sharp but beds installed at depths exceeding 50-feet may be considered as being deep. These have been made of steel rails, steel pipe, graphite or high silicon cast iron with the different materials installed in soil or in backfill in deep drilled holes.[18, 19] Figure 8 illustrates one method in which

graphite rods are installed inside a steel casing with coke breeze backfill.

Some of the advantages claimed for deep ground bed installations are:

1. They provide a low resistance ground bed in high resistivity soil, thus ensuring lower power costs.

2. They provide better current spread than from normal shallow type ground beds by allowing the current to penetrate to and follow the deep lower resistivity strata for greater distances.

3. Interference with foreign structures is reduced in the vicinity of the ground bed. This is important in urban or other congested areas.

4. Resistance to earth is changed only slightly with variations in rainfall or surface moisture.

5. Right of way costs are reduced over conventional type ground beds.

6. Extensive surveys to locate pockets of low resistivity surface soil are not needed.[20]

Design of Ground Bed

The total circuit resistance of the cathodic protection system shown in Figure 1 consists of the resistance to earth of the anode, the resistance in the cable connection between the anode and the protected structure and the resistance to earth of the structure itself. The latter value can be obtained using a Megger or Vibroground and the well known three-pole measurement. Wire tables should be used for cable resistances. The resistance to earth of the anode can be estimated from Figure 5 or from Tables 1 and 2.

A knowledge of the current needed should be estimated or determined from preliminary checks. It is good practice to install additional anodes to take care of future current demand due to additional connections or because of deterioration of coatings on the protected structure. The voltage needed for the current source will be the product of the current and the total circuit resistance plus approximately 2 volts to take care of the galvanic potential difference between steel and graphite. Details of design have been covered previously by others.[12]

The following example will illustrate the use of Tables 1 and 2:

There was a need for a ground bed of graphite anodes in coal coke breeze backfill to be placed in 3000 ohm-centimeter soil to supply 56 amperes of current. Total length of 1/0 copper cable is 500 feet and its resistance from copper wire tables is 0.05 ohm. Measured resistance of protected structure to earth is 0.1 ohm.

Maximum current recommended for a 3 inch by 60 inch graphite rod in backfill is 4 amperes so that minimum number of anodes is 56/4, or 14.

Resistance to earth of each anode in 12 inch diameter by 96 inch long column of backfill from Table 1 is 2.06 ohms for 1000 ohm-centimeter soil, and by proportion is 6.18 ohms for 3000 ohm-centimeter soil.

Assume a spacing of 15 feet between anodes. Then the correction factor for

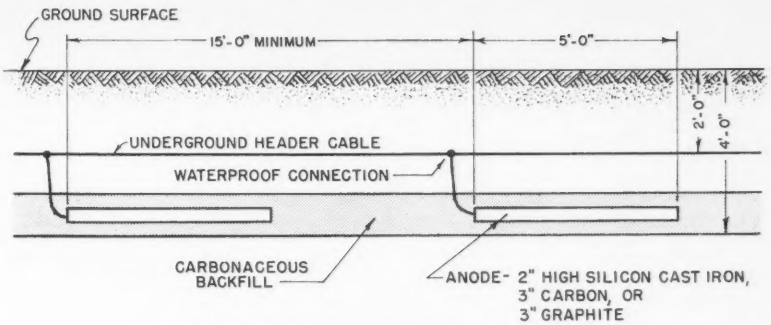
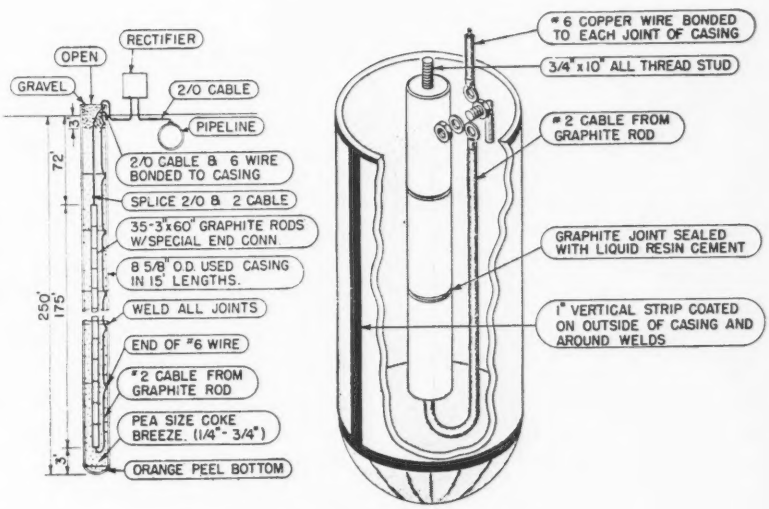


Figure 7—Typical horizontal anode installation.


OPEN
RECTIFIER
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2/0 CABLE
PIPELINE
3'
72'
2/0 CABLE & 6 WIRE BONDED TO CASING
SPLICE 2/0 & 2 CABLE
35-3"x60" GRAPHITE RODS W/SPECIAL END CONN.
8 5/8" O.D. USED CASING IN 15' LENGTHS.
250'
175'
WELD ALL JOINTS
END OF #6 WIRE
#2 CABLE FROM GRAPHITE ROD
PEA SIZE COKE BREEZE. (1/4"- 3/4")
3'
ORANGE PEEL BOTTOM
#6 COPPER WIRE BONDED TO EACH JOINT OF CASING
3/4"x10" ALL THREAD STUD
#2 CABLE FROM GRAPHITE ROD
GRAPHITE JOINT SEALED WITH LIQUID RESIN CEMENT
1" VERTICAL STRIP COATED ON OUTSIDE OF CASING AND AROUND WELDS

Figure 8—Deep ground bed installation.

14 anodes from Table 2 is 1.40. Anode group resistance is $\frac{6.18}{14} \times 1.40$ or 0.618 ohms. Total circuit resistance of anode group, cable and structure is: $0.618 + 0.05 + 0.1 = 0.768$ ohm.

Substantial savings in power costs can be realized by reducing the total circuit resistance and this can be accomplished by increasing the number of anodes or the separation between them or by increasing the cable size.

To illustrate this, assume the same size cable and change the number of anodes to 20 with a spacing of 20 feet between anodes;

From Table 2, the correction factor is 1.35

Anode group resistance is

$$\frac{6.18}{20} \times 1.35 = 0.416 \text{ ohm}$$

Total circuit resistance is then, $0.416 + 0.05 + 0.1 = 0.566$ ohm.

The ratio of resistance for a 20 anode bed to a 14 anode bed is 0.566/0.768 or approximately three-fourths.

The saving in power costs will depend upon the power rate. This saving will be overcome somewhat by additional investment costs. Calculations comparing the decrease in power costs with interest charges on investment and other factors should be considered.[12, 21]

Water Submerged Structures

Impressed current anodes made of steel, graphite and high silicon cast iron have been used successfully in all types of water submerged conditions. In addition to these materials, the use of aluminum alloy impressed current anodes has been extensive in water tanks and other locations.[11] Platinum impressed current anodes have been installed in water tanks, inside of water pipelines, and as anodes for protection of ships and submarines.[22] Of recent interest is the use of lead alloy anodes in sea water.[23]

Many vessels containing electrolytes need cathodic protection and could be so protected if anodes could be placed in them. The main problems here are (1) finding room for anodes within limited spaces, (2) placing anodes so that they will be in proper position with respect to surfaces to be protected, (3) finding suitable anode shapes and sizes, (4) selecting anode materials that will have suitable service life in the electrolyte involved and whose decomposition products will not contaminate the electrolyte,

and (5) providing leak-free insulated conductors through the vessel walls. Such applications need individual study and sometimes much ingenuity on the part of corrosion engineers.

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High Temperature Corrosion in Refinery And Petrochemical Service*

By E. N. SKINNER, J. F. MASON and J. J. MORAN

Abstract

The paper is concerned with the corrosion phenomena likely to influence the selection of materials for refinery service at elevated temperatures. The problems of oxidation, sulfidation and carburization are discussed in detail and consideration is given to the effects of condensate corrosion and residual oil ash corrosion. The contributions of various alloying elements in the common engineering alloys to their physical and mechanical behavior as well as to their corrosion resistance at elevated temperatures are discussed. Basic considerations for the selection of suitable alloys to withstand high temperature corrosive environments are outlined. 8.4.3

HIGH TEMPERATURE corrosion is a matter of particular concern in the petroleum and related petrochemical industries. Methods used to investigate this phenomenon are in many cases complex. Although high temperature corrosion in general appears simpler in concept than aqueous corrosion, the fact that the reactions proceed at some temperature far removed from atmospheric introduces serious complications. For example it is not usually convenient to observe a high temperature reaction at the service temperature; yet the corroded material cooled to room temperature may only remotely resemble the material participating in the reaction. In addition, surface scales which are continuous and protective at the operating temperature often crack and spall before they can be cooled for examination. Or the scale, the alloy, or both may undergo phase changes in the interval between the operating temperature and the temperature convenient for observation and examination.

The same kinds of difficulties are encountered in attempting to define precisely the corroding medium. Gas samples obtained at high temperatures may have changed their character completely before they are analyzed at some lower temperature. A further complication arises because thermal diffusion is operative at elevated temperatures and although the composition of an alloy can be determined precisely enough at room temperature, diffusion may allow some minor constituent to concentrate at the reaction interface and exert an influence out of proportion to its quantity in the body of the alloy.

Despite the difficulties inherent in its study, considerable progress has been made in the past 30 years to understand the mechanism by which metals corrode at high temperatures. Several rate equations to describe the progress of corrosion on at least a semi-quantitative basis have been postulated and a vast body of literature devoted to justifying the equations or to explaining deviations from them is being accumulated. Such work is necessary and desirable but its application to the selection of materials for high temperature service is hampered by one additional perversity of temperature. Almost all of the fundamental work on oxidation and the other manifestations of high temperature corrosion is limited to relatively thin films at constant temperature under minimum stress. These limitations are necessary because to have quantitative reproducibility of results it is essential that a continuous, adherent film be maintained on the alloy. However, stress, temperature fluctuation, phase changes, and the increasing thickness of the scale itself all tend to disrupt this continuity. In the end it may be, and often is, the tenacity of the scale, its resistance to cracking and spalling under adverse conditions, rather than its inherent resistance to attack under ideally controlled conditions which determine the suitability of an alloy for a given service.

The basic material of construction is mild steel and the substitution of a more highly alloyed steel must be justified on a cost versus performance comparison with it. At temperatures above about 950 F, however, the presence of chromium is required to prevent excessive scaling; the actual amount needed is roughly proportional to the anticipated service temperature. For somewhat more rigorous service at the higher temperatures and particularly where high temperature strength is necessary, various austenitic stainless steels and nickel-base alloys are employed. The following discussion then will consider a number of the factors influencing the choice between the foregoing alloys for refinery service. The characteristics of the austenitic materials will be considered in somewhat greater detail than the others.

Oxidation

Air oxidation has been studied more thoroughly than any other high temperature reaction and has served as the basis for most of the fundamental work in the field. With the exception of gold, but including platinum, no pure metal and no alloy is stable in air at room temperature. Thus the problem is seldom to determine whether the reaction will take place but is reduced to a discussion of reaction rates. Unfortunately this is by no means a simplification as kinetic problems are generally far more complicated than thermodynamic ones. Since at moderately high temperatures the reaction at the gas-metal interface will go to completion rather quickly, it is the reaction product in the form of an intermediate layer between the alloy and the gas which controls the rate and affords protection from continued rapid reaction.[1]

Most theories, with ample experimental justification, postulate a diffusion mechanism for protective scale growth which usually results in a parobolic rate law; (i.e., the scale growth is proportional to the square root of the exposure time). But, as was mentioned above, the person responsible for materials selection must go beyond the fundamental mechanisms and consider the alloys in the context of the service conditions. For example, when tested at constant temperature, resistance to oxidation of Fe-Ni-Cr alloys appears to be largely a function of chromium content and the ratio of iron to nickel in the balance of the alloy has only a secondary effect. If, however, cyclic temperature conditions prevail the order of resistance may be significantly modified and the total compositional balance as it affects the physical properties of the alloy and the scale will play a more important role. Thus increasing the nickel content exerts a beneficial effect in that it reduces the differential in thermal expansion between the oxide and the base metal and correspondingly reduces the stress at the scale-metal interface.[2] The result is illustrated in Figure 1.

Elements other than chromium of course may influence the rate of scale formation under constant temperature conditions. Silicon is remarkably effective in steels even when present in relatively small quantities. In fact at lower chromium contents as seen in Figure 2[3], silicon is more effective than chromium on a weight percent basis and improves the oxidation resistance to a significant extent over a wide range of chromium contents.[4]

Aluminum as well as chromium improves the oxidation resistance of Fe-base alloys[5] (Figure 3)[3] although the use of copious quantities of this element is not desirable because of adverse effects upon mechanical properties. This difficulty may be avoided if the aluminum is applied to the surface layers only, by spraying, dipping, cementation, etc. This practice is particularly applicable to low alloy steels as a means for improving oxidation resistance at moderate temperatures. It is also useful at high temperatures but then must include an additional diffusion treatment to create a sturdy alloy bond and to eliminate the presence of metallic aluminum on the surface. This latter is an obvious necessity when the melting temperature of aluminum will be exceeded in service.

Returning to the essentially unmodified iron-nickel-chromium system of alloys, the maximum temperature limits for constant temperature exposure to air oxidation without appreciable scaling are roughly proportional to the chromium contents of the alloys; for example, 1400-1450 F for 12 Cr alloy and 1550-1600 F for 18-8 and 17 Cr ranging up to 2000 F for 25 Cr-12 Ni, 25 Cr-20 Ni and 27 Cr-bal Fe as well as the Cr-bearing nickel-base alloys.[6] These limits as noted previ-

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ously would be reduced under cyclic heating conditions, probably more than 100 F for the high-Fe alloys.

Unexpected failures from simple oxidation are rare and generally unnecessary as the capabilities and limitations of the various heat-resistant steels have been thoroughly explored and the results widely publicized, although even a well engineered design may be defeated by some unforeseeable upset in operating conditions. Of course the serious effects of a high temperature exposure sometimes become manifest only after shut-down when condensates have the opportunity to deposit. This subject will be considered at length later.

Sulfidation

Sulfur attack is second only to air oxidation in frequency of occurrence and is of even greater consequence because the resultant deterioration is likely to be much more severe. It should be noted that sulfur attack may be encountered not only in the processing but also in the consumption of petroleum products. Invariably when sulfur is present in a harmful form it dictates the selection of materials of construction and may even necessitate some compromise on strength in order to obtain maximum resistance to sulfidation.

Sulfur attack, like oxidation, proceeds by conversion of the metal to a sulfide scale which may persist on the surface and offer some measure of protection to the remaining sound metal. Sulfidation is generally more destructive than oxidation, however, because sulfide scales are more friable, more subject to exfoliation, than are oxides. Further, oxides, at least those formed on heat resistant alloys, melt at relatively high temperatures, above the melting temperature of the alloy on which they form, whereas sulfides are comparatively low melting and in some systems may form even longer melting eutectics with the metal being attacked. The composition of the underlying metal also influences the melting temperature of the sulfide scale.[7] (Figure 4).

Again chromium, in combination with iron, nickel or both is the major contributor to sulfidation resistance. Unalloyed Fe will be converted rather rapidly to scale and pure nickel is attacked so avidly that it will be completely embrittled intergranularly before a significant amount of massive scale is able to form. Among the minor elements silicon and aluminum, as with oxidation, also afford some protection.

In addition to the usual factors of time, temperature and concentration of corrodent, sulfidation is markedly dependent upon the form in which the sulfur exists and an alloy possessing useful resistance to sulfur in one form may actually undergo accelerated corrosion when the sulfur is present in another form.

The three major categories of interest for refinery services are:

1. Organic sulfides
2. Hydrogen sulfide
3. Sulfur combustion products.

Organic Sulfides

In refinery services involving the handling of sour feed stock at moderately elevated temperatures, straight Cr or Cr-Moly steels have traditionally been employed with good success. Alloys of the 5 Cr-½ Moly type have been entirely adequate for processing feed stocks containing as much as 5 percent sulfur. Of course, where the 5 percent Cr is found lacking, chromium levels up to 12 percent may be employed. Crude oil heaters and the bottoms of distillation columns where aqueous condensates do not exist as temperatures are above 750 F, are representative of service conditions wherein the moderately alloyed Cr steels are satisfactory. (See Figure 5).[8]

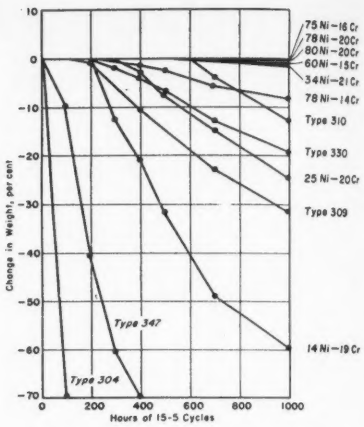

Figure 1—Effect of nickel content on air oxidation of alloys. Each cycle consisted of 15 minutes at 1800 F followed by a 5 minute air cooling.

Hydrogen Sulfide

The materials mentioned above were used without undue difficulty until the advent of the catalytic reforming process as a source for high octane fuels. Here the sulfur is present as hydrogen sulfide under considerable pressure and the character of the attack is considerably modified. The sulfide-forming reaction of iron with hydrogen sulfide does not result in the formation of the relatively adherent continuous scale usually found on chromium steels exposed to sulfur.[9,10] Unlike the experience with organic sulfides, moderate chromium levels actually appear to impair corrosion resistance to H_2S.[11] The rate of corrosion is thus increased but, even more annoying, the readily exfoliated FeS scale deposits and plugs the unit. Studies and an exhaustive survey of this phenomenon revealed that still higher chromium contents, 17 percent and above, would minimize the difficulties and that the best way to obtain these levels plus adequate fabricability was to use the 18/8 stainless steels. (See Figure 6).[10,11] Another method which successfully inhibits the action of H_2S is to apply aluminum to the surface of chromium steels. The Al-rich film, provided it remains intact on the surface, is essentially inert to the effects of H_2S.[10]

Sulfur Combustion Products (SO_2)

This is the least harmful form and does generally pose much of a materials selection problem. Particularly if an oxide film is formed prior to exposure to the SO_2-bearing gas and the atmosphere is continuously oxidizing, little change from the rate of simple air oxidation will be observed. In any event the mixed oxide-sulfide layer is reasonably effective in slowing the absorption of sulfur even though it may be less adherent than the uncontaminated oxide formed in air.[12] Alloys high in chromium provide useful resistance in this environment and aluminum and silicon may also contribute to the stability of the oxide and its adherence to the base metal. In general, tube supports and spacers, rather than the tubes, which are cooled by the product stream, suffer more attack from combus-

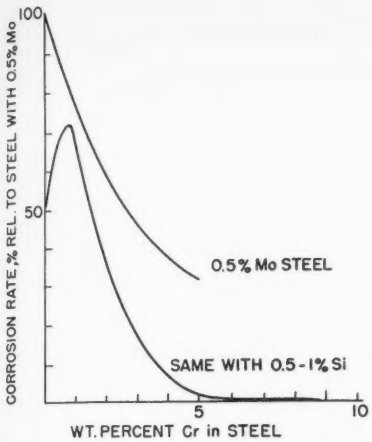

Figure 2—Influence of silicon on the oxidation rate of 0.5 percent Mo steel at various chromium levels at 1250 F. (Plotted after data in Timken Digest).

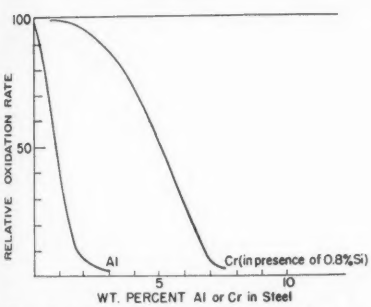

Figure 3—Influence of chromium or aluminum on oxidation rates of steel in air at 1470 F. (After Houdremont, and Houdremont and Schottky).

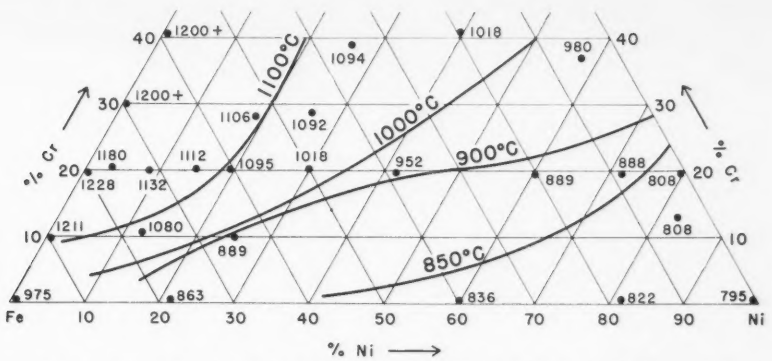

Figure 4—Melting temperatures of corrosion products formed on Fe-Ni-Cr alloys on exposure to hydrogen sulfide.

TABLE 1—Pack Carburization Test*

Alloy	Composition	Silicon Content, Percent	Increase in Carbon Content, Percent**
"80-20"	80 Ni, 20 Cr	1.46	0.06
Inconel Alloy	78 Ni, 15 Cr	0.15	0.11
"60-15"	60 Ni, 15 Cr	1.28	0.02
Incoloy Alloy	34 Ni, 21 Cr	0.34	0.04
Type 330	35 Ni, 15 Cr	0.47	0.23
Type 330	35 Ni, 15 Cr + Si	1.00	0.08
Type 310	20 Ni, 25 Cr	0.38	0.02
Type 314	20 Ni, 25 Cr + Si	2.25	0.03
Type 309	12 Ni, 25 Cr	0.25	0.12
Type 347	8 Ni, 18 Cr + Cb	0.74	0.57
Type 321	8 Ni, 18 Cr + Ti	0.49	0.59
Type 304	8 Ni, 18 Cr	0.39	1.40
Type 302-B	8 Ni, 18 Cr + Si	2.54	0.22
Type 446	28 Cr	0.34	0.07
Type 430	16 Cr	0.36	1.03

* 40 Cycles of 25 Hours at 1800 F (Carburizer renewed after each cycle).
** By Bulk Analysis.

tion products. Alloys high in chromium (20-30 percent) with sufficient nickel (12-20 percent) to make them austenitic for better strength are frequently employed, usually as castings.

Carburization

Another type of high temperature reaction that can influence the performance of heat-resisting alloys is carburization. The phenomenon is not truly corrosion in the sense that metal loss occurs; nevertheless, it may have such profound influence upon the properties of furnace alloys that it deserves consideration in the selection of refinery and petrochemical materials.

It appears that the initial stage of carburization involves the adsorption of carbon—mainly from a gas, occasionally from a liquid, and only rarely from a solid—upon the metal surface. If the temperature is high enough, carbon can diffuse into the alloy and cause the precipitation of stable carbides of chromium and, to a lesser extent, iron. Since nickel forms a carbide of only limited thermal stability,[13] the principal result of carburization of high nickel alloys is to remove chromium from solid solution. The formation of hard and brittle carbide phases within the structure has the general effect of raising the hot strength of the alloy and at the same time causing a reduction in ductility. The embrittling effect is usually most severe when conditions have been favorable to the formation of a nearly continuous network of carbides in the grain boundaries, and least severe when there have been temperature fluctuations promoting the coalescence of the carbide phase.

The process of carbon absorption may also have an effect upon the chemical properties, depending upon the degree to which the original Cr content is immobilized. Accordingly, one might expect to find the behavior of an alloy in resisting sulfur attack or oxidation—both specific to the chromium content—to be adversely affected by the occurrence of carburization.

In addition to reacting with chromium, the inward diffusing carbon will, of course, combine with Ti and Cb, the carbide stablilizing elements employed in stainless steels. Carbide stabilization, or the use of extra low-carbon grades, is not necessary to ensure high temperature corrosion resistance. This is because "sensitization," the well-known chromium carbide precipitation at the grain boundaries, is only of importance under conditions favoring the existence of an electrolyte. It is true, however, that these conditions may be encountered during shut-down periods if corrosive condensates are present. While the usual means of combatting this type of attack is to use either extra low-carbon alloys or one of the stabilized grades, obviously neither would continue to exhibit aqueous corrosion resistance if extensive carburization has taken place during service.

As far as the effect of alloy composition on carburization is concerned, field experience and laboratory examination of field exposed test pieces have indicated that the resistance seems to depend importantly upon the chromium content.[14] A comparison of the amount of carbon absorbed by Type 430, on the one hand, and Type 446 under identical conditions of exposure shows that in the higher chromium alloy the diffusion of carbon is much slower. In the austenitic steels, again, chromium is the important element, with its effectiveness enhanced at higher nickel contents. As an example, in one test the amount of carbon absorbed is much less for Type 310 than for Type 309 or 304. (Table 1). Among the auxiliary alloying elements, as shown, silicon in amounts up to about 2.5 percent is most effective in preventing carbon absorption, especially in the 18/8 and 25/20 base compositions where such modifications are known as Type 302B and 314, respectively.

In furnace tubes, one of the commonest forms of carburization results during decoking, if a deposit of solid carbon is allowed to burn improperly in a more or less uncontrolled fashion. These conditions can lead to very high local temperatures, which, aside from the likelihood of producing bulges from overheating, also introduce the hazard of carbon absorption and reduction of ductility in the location of the bulge. (See Figure 7).

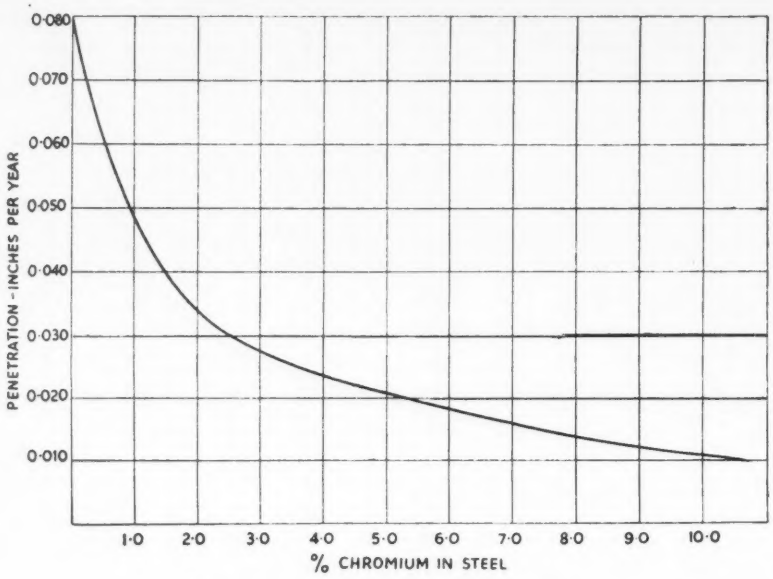

Figure 5—Corrosion of alloy steels in hot oil at 775 F.

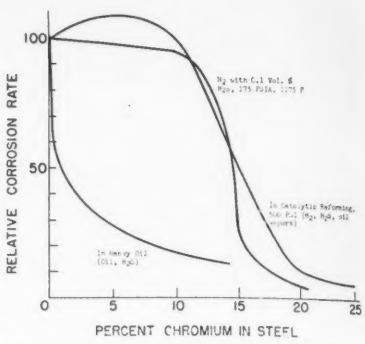

Figure 6—Influence of chromium on sulfidic corrosion of steel. (Data after Backensto, Drew and Stapleford, Wright, and Atlantic Refining Co. via Sorell and Hoyt).

TABLE 2—Results of Test in Top of Bubble Towers

Metal	Penetration Rate, In. Per Yr.	
Mild steel	Destroyed	0.050
5% nickel steel	Destroyed	....
18% chrome—8% nickel	Destroyed	0.025
17 chrome—11 nickel—3 moly	0.053	....
Monel 69 nickel—29 copper alloy	0.003	0.007
Nickel	0.006	0.007
Ni-Resist cast iron	0.051	0.013
Cast iron	0.181	0.043
Temperature	250 F	Approx. 200 F.
Crude	West Texas	Michigan

Catalysis

Carburization and coke formation are associated in petroleum and petrochemical service and it is natural to inquire more deeply into this relationship. In particular, it would be desirable to know whether the materials of construction are in any way responsible for the amount of coke deposited. There are widely divergent opinions regarding the possibility and particularly the effectiveness of various tube materials in catalyzing the decomposition of hydrocarbon gas streams at elevated temperatures. It is difficult though to arrive at an unambiguous conclusion because invariably the amount of uncatalyzed thermal cracking, affected some by the physical properties of the container material and considerably by operating variables, will obscure the extent of any catalytic effects which may have occurred.[15]

It is known that iron, nickel and cobalt, under the proper conditions, will act to catalyze the decomposition of hydrocarbons to hydrogen and carbon. For efficient action the metal must have a high specific surface, that is the particle size should be small, and the temperature should be above approximately 300 C.[16] The same metals in tube form have been reported by some investigators to be catalytic[17] and by others to be "practically non-catalytic."[15] Presumably these contradictory conclusions result from the ease with which materials of low specific surface can be poisoned. Steam, H_2S and CO_2 among others have been cited as possible poisons.[15] One might also note the apparent anomaly that whereas binary alloys of 80 Ni-20 Cr and 70 Fe-30 Cr were reported as non-catalytic, investigators have found 74 Fe-8 Ni-18 Cr (that is, 18/8 stainless steels) to be catalytic in some instances.[15] Again one must conclude that the amount of poisoning rather than some intrinsic catalytic property of the alloy is controlling.

In deciding the cause of coking, attention should be paid to the form of the carbon in the deposit. Catalytic carbon is soot-like, does not adhere tightly to the walls and is likely to be carried out of the furnace with the reaction products if the gas stream is moving with a moderately high velocity. Moreover this type of carbon will contain a certain portion of the metal container and will ultimately cause destruction of the container. Lastly, this type of carbon, probably because of the entrained metal particles, is itself catalytic.[15]

Petrochemical coke, by contrast, is usually hard, dense, adherent; not being catalytic itself, it masks surface activity as it forms. Many furnace operators have concluded that operating procedure rather than tube materials is of primary importance in minimizing coking and no tube materials have been found to eliminate coking completely.[18] This conclusion is at least partially justified by controlled tests comparing 27 Cr-bal Fe (generally conceded to be non-catalytic) with 18/8 stainless steels which showed the difference in the amount of coke formed in the two materials to be insignificant.[19]

On balance it appears that catalytic action of tube walls should exert only a minor influence on coke deposition, as compared with thermal decomposition, because of the relative inefficiency of massive forms of metals and the introduction of known poisons with the feedstocks.[15]

Deposits

Another insidious form of high temperature corrosion is associated with the presence or deposition of molten phases on the surface of the metal structure. Two common sources of such phases are the products of combustion of residual fuels and welding fluxes not completely removed after welding. Although the noxious agents, V_2O_5 and sodium salts in the one and various fluoride-containing mixtures in the other are different, the mechanism of attack is in all its essentials the same.

A molten deposit forms on the metal and fluxes the oxide from its surface. Even in the absence of impurities other than air, accelerated oxidation will occur where the protective film is removed.[20] But if additional impurities such as sulfur are present, rapid and destructive attack is likely. This comes about because under certain conditions the molten deposit will serve to collect and concentrate such elements as sulfur, present in the gas in normally harmless concentrations, and convey them to the now unprotected metal surface beneath the deposit.[21] (See Figure 8.)

It should be noted that the fluxing agent acts as a kind of catalyst rather than an active participant in this type of corrosion as it is not depleted even if the original source is removed. There is no generally satisfactory metallurgical solution to this problem and the most acceptible correctives are to remove all traces of the molten phase from contact with the metal, to keep the temperature below the fusion temperature of the deposit, or, in the case of residual fuels, to use an additive which will raise the fusion temperature above the temperature of operation.[22]

Aqueous Corrosion

As mentioned previously, chromium-bearing steels are generally used to resist attack from hot (above 600 F) sulfur-containing oils. But in the top section of distillation columns where the tempera-

Figure 7—Upsetting and carburization of 34 Ni-Cr alloy tube during decoking of ethylene heater.

TABLE 3—Results of Some Studies of Corrosion by Naphthenic Acids

Metal	Penetration, In. Per Yr.
Mild steel	0.016
18 chrome—8 nickel	0.024
18 chrome—8 nickel—3 moly	<0.001*
16 chrome—13 nickel—3 moly	0.001*
Inconel alloy	<0.001*
Monel alloy	0.001
Nickel	<0.001
Ni-Resist cast iron	0.011
Cast iron	0.008

Temperature ..... 550 F
Location ..... Column of Vacuum Unit

* Three applicable metals. Possible sulfur attack (above 500 F) precludes Monel or nickel. Monel in use at temperature below 500 F.

ture is below the dew point, an aqueous phase can exist which most generally causes hydrolysis of the calcium and magnesium chloride salts to occur, with the formation of small amounts of hydrochloric acid. This together with wet H_2S that may also be present can often lead to serious corrosion in many of the more commonly available metals and alloys. Table 2 shows the degree or extent of corrosion that may be encountered.[23] It will be noted that Monel* nickel-copper alloy possesses a useful degree of corrosion resistance and it has been adopted as the more or less standard material for linings, bubble caps, trays, reflux and rundown lines, as well as overhead condenser tubes and accumulators to combat this acid corrosion.

Condensate Corrosion

In the operation of equipment used for the combustion of hydrocarbon fuels, the principal problem that may be encountered is attack by the presence of sulfur compounds and this can usually be taken care of by the use of the chromium alloy or chromium-nickel steels. However, the problem of wet corrosion is often encountered when the equipment is shut down or when an opportunity is provided for the gases of combustion to drop below the dew point. Under these conditions, an acid condensate forms which can be highly corrosive to the materials commonly used for resistance to the sulfur-bearing gases at combustion temperatures. The corrosivity of the condensate is due to the presence of both sulfuric and sulfurous acids. Experience has shown that this has been the cause of much equipment failure and in order to overcome it, it is sometimes necessary to use such alloys as Types 316 and 317 stainless steel as well as Ni-o-Nel* nickel-iron-chromium alloy and Carpenter 20.** In some extreme cases, even Hastelloy C*** has been used. All of these materials are resistant to corrosion by the sulfuric and sulfurous acids generally found in condensate from the combustion of fuels. Unless steps are taken to neutralize such acids or sweep them from the equipment when it comes down, corrosion can be serious and it may be necessary to employ the molybdenum-bearing materials mentioned above.

Figure 8—Sulfidation which occurred beneath welding flux when furnace atmosphere contained high sulfur content. Areas not contaminated by flux were essentially unaffected by the sulfur. Sample is 78 Ni-15 Cr weld metal on 33 Ni-21 Cr base metal. Ten percent oxalic, electrolytic, approximately 50x.

Naphthenic Acid Corrosion

Certain crude oils, notable those from Venezuela and Southern California, contain in addition to sulfur compounds and chloride salts a fairly good concentration of naphthenic acids. Experience has shown that because of the presence of the latter, corrosion can become more active at elevated temperatures without the necessity of water being present. Studies have proved that it is possible

* Trademark of The International Nickel Co., Inc.

** Trademark of The Carpenter Steel Co.
*** Trademark of Haynes Stellite Co.

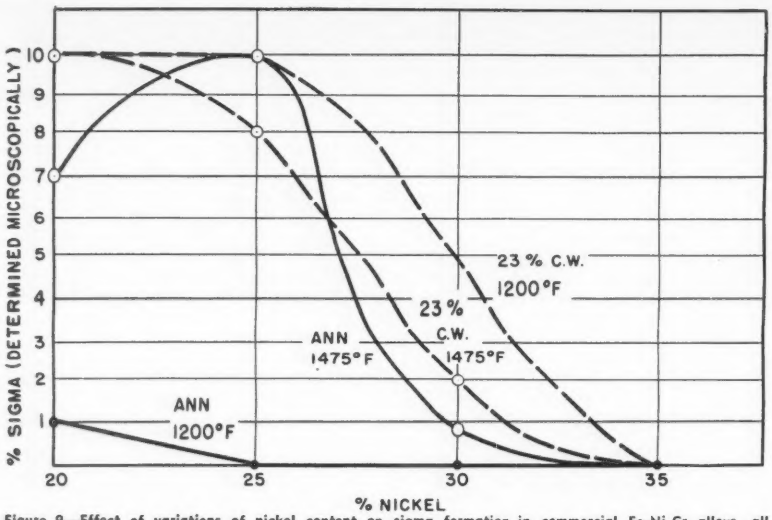

Figure 9—Effect of variations of nickel content on sigma formation in commercial Fe-Ni-Cr alloys, all containing 25 percent Cr. with and without prior cold work. Samples exposed 3000 hours at indicated temperatures (after Foley and Krivobok).

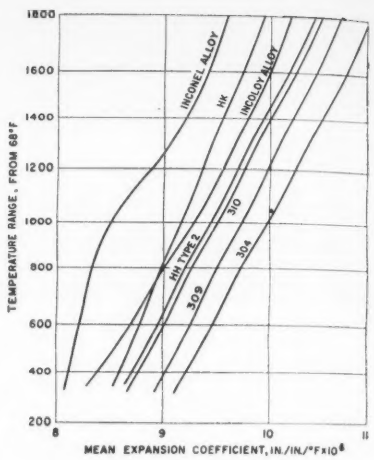

Figure 10—Thermal expansion of alloys.

to make a practical differentiation between naphthenic acid and sulfur corrosion by observing the corrosion phenomena on such materials as steel. Streams high in naphthenic acid generally produce very characteristic sharp-edged holes or, in cases where the stream is at high velocity, sharp-edged streamlined grooves. Such typical forms of attack have never been observed when processing crudes free from naphthenic acids. Also, in the presence of naphthenic acids, the critical temperature at which severe corrosion may occur is considerably lower than in the case where only sulfur is present.

Steps have been devised for mitigating naphthenic acid corrosion by such actions as pretopping at relatively low temperatures to effect its removal or by neutralization with caustic soda or lime. Where this cannot readily be done, it is necessary to resort to the use of alloys possessing satisfactory resistance to corrosion.

Typical of the severe corrosion that can occur in the presence of naphthenic acid during the vacuum distillation of a Venezuelan crude is shown in Table 3. It will be noted that Types 304 and 316 stainless steel as well as Inconel alloy are outstanding in their corrosion resistance under these conditions. While both Monel alloy and nickel show useful corrosion resistance in this test they should never be used under these conditions because of the presence of sulfur compounds and the possibility of embrittlement at temperatures in excess of 500 F.

Under conditions of increased fluid velocity it has been found that the Type 502 steel offers a reasonable degree of corrosion resistance except perhaps for furnace and heat exchanger parts where it is often very irregularly attacked, (chiefly in the form of pitting). This has also been the experience with Types 304, 321 and 347 stainless steels and they have not proved to be altogether reliable because of severe pitting attack. Under these conditions it generally is necessary to resort to the use of such materials as Type 316 stainless steel and Inconel alloy.

Physical Properties

For most high temperature service, factors other than merely adequate corrosion resistance must be taken into account to justify the selection of a particular alloy. In some cases structural stability may be the deciding property in the selection of several materials of equivalent corrosion resistance. Most of the straight-chromium stainless steels embrittle during prolonged exposure at certain temperatures below 1000 F and in addition 27 Cr-bal Fe (Type 446) may become glass-brittle from sigma formation as a result of exposure at temperatures only slightly above 1000 F.[24] Many of the austenitic stainless steels also form sigma but at somewhat higher temperatures and not usually to the same extent as Type 446. It should be noted that cold work and variations in minor alloying elements exert considerable influence on the rate and the total amount of sigma formed.[25] (See Figure 9). Sufficient nickel will ensure that sigma does not form in austenitic alloys of the iron-nickel-chromium system even though in some cases ferrite (of the high-Cr type) is present.[26]

Refinery flare tips are required to resist radiant heat and a sulfidizing atmosphere coupled with severe vibration from combustion resonance. Types 304, 309 and 310 stainless steels have been used in the past and maintenance has been a recurrent problem as premature failures from cracking have been experienced. Recent trials with a 33 Ni-21 Cr alloy have shown this alloy to resist cracking and thus measurably to extend the trouble free service life.[27] X-ray and metallographic examinations have revealed sigma to be present in the stainless steels, but sigma will not form in the higher nickel alloy. Thus although it has rightfully been claimed that sigma does not seriously impair the strength or ductility of alloys at high temperatures, this experience indicates that it may harmfully affect high temperature fatigue behavior.

Carbide precipitation may sensitize the alloy to certain aqueous corrodents, but it has only a secondary influence on high temperature behavior. The small loss in ductility is relatively unimportant and any effects of chromium depletion adjacent to grain boundaries are not apparent at temperature. Actually prolonged high temperature service will eventually stabilize the alloy, as a temperature which will precipitate carbides will in most cases be high enough to cause subsequent migration of more chromium to the depleted areas if time at temperature is allowed.[28]

Thermal expansion is an important variable in some circumstances. If dissimilar metals are used in conjunction at high temperatures it is essential to establish that their thermal expansivities are compatible. In general, the ferritic alloys have the lowest thermal expansivities, the austenitic stainless steels the highest with the nickel-base alloys being intermediate to the two (See Figure 10). If expansion is constrained or minimum distortion required, expansivity may also be an important factor in alloy selection.

Fabricability in general and weldability in particular deserve extensive treatment which will not be attempted here. Suffice to say that considerable care must be exercised to obtain sound, crack-free welds and that such difficulties are pronounced with very high-chromium ferritic alloys and, to a lesser extent, with some of the austenitic stainless steels. The major problems with the latter are mutually exclusive; it is possible to deposit crack-free welds in these alloys or to deposit welds which will be stable and not embrittle with time. It is difficult, however, to deposit a crack-free weld which will not embrittle with time. [29] This occurs because a controlled quantity of ferrite is usually incorporated into the otherwise austenitic weld metal to aid in reducing the incidence of cracking during welding but induces susceptibility to long time embrittlement. Thus attention must be paid to the long term requirements as well as to the immediate concern with

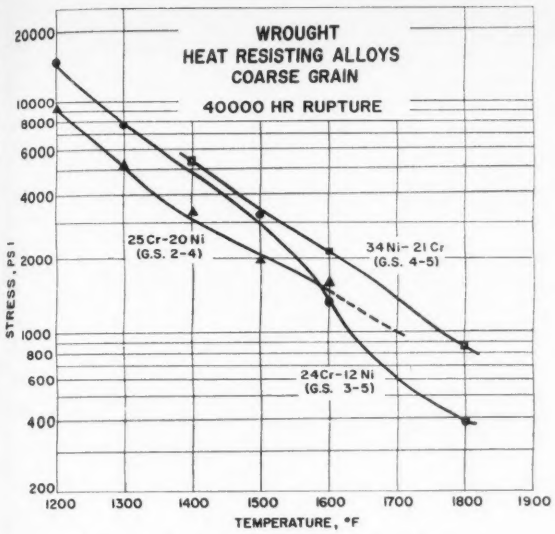

Figure 11—High temperature strength levels of alloys.

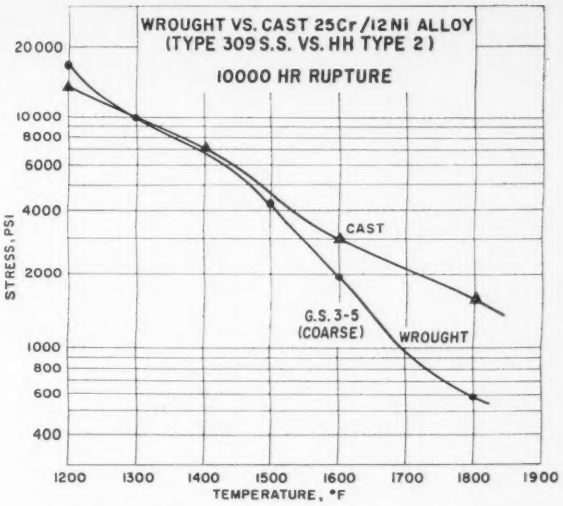

Figure 12—High temperature strength levels of two alloys.

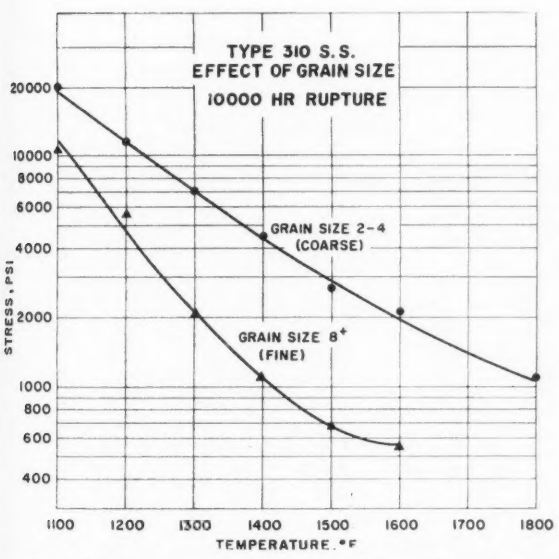

Figure 13—High temperature strength level of Type 310 stainless steel.

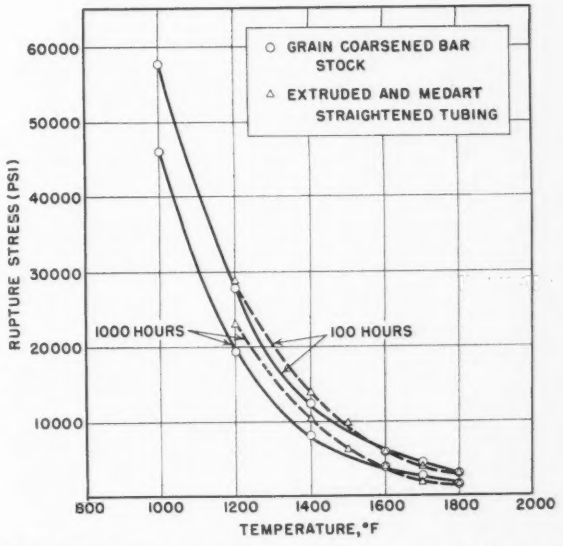

Figure 14—Rupture strengths (100 and 1000 hour) of extruded tubing and grain coarsened bar stock of 34 Ni-21 Cr. alloy.

ease of welding when joining stainless steels for high temperature service.

Mechanical Properties

At comparatively low temperatures, up to the vicinity of 1000 F, designs may be based on the short time properties, yield and tensile strengths, whereas at temperatures much above 1000 F the phenomenon of creep is controlling. Ferritic alloys are generally more than adequate at the lower temperatures, but where creep conditions prevail the austenitic alloys possess substantially better strength. Among the austenitic materials, fairly wide variations in strength levels are found at high temperatures. The higher alloy-containing materials appear superior at the higher temperatures (Figure 11) and of course additional increments of strength may be obtained by adding age hardening elements, strong carbide formers etc. However these latter additions tend to make alloys more difficult to fabricate or more sensitive to temperature variation and thus have only limited applicability in refineries and petrochemical plants.

Processing variables, within a given alloy composition, may also exert a considerable effect upon the mechanical behavior of the alloy. For example at very high temperatures the cast version of an alloy invariably has greater strength than its wrought counterpart but at lower temperatures the situation is reversed.[20,21] (See Figure 12). The superiority of the former at high temperatures is often ascribed to the considerably coarser grain size of the cast product. Undoubtedly the grain size contributes but it should also be borne in mind that in a casting, with no requirement that it be easily deformed at some temperature reasonably below its melting point, the levels of residuals and minor strengthening elements may be substantially higher than in the wrought and these too contribute significantly to the high temperature strength. Whatever the actual cause, serious consideration must be given to castings when maximum strength at extreme temperatures is required.

With the wrought alloys knowledge of the prior processing history is essential if an accurate estimate of the high temperature behavior is to be made. The effect of a solution anneal, which results in a relatively coarse grain size, is considerable at the higher temperatures al-

though again, as with castings, the finer grained material is superior at lower temperatures.[31] (See Figure 13). One should be aware that the majority of austenitic stainless steels, unless otherwise specified, are furnished in the fine grained condition.

Because a certain percentage of the tubing supplied to the petroleum and petrochemical industries is extruded rather than pierced and cold drawn the effect of this method of processing on high temperature strength is of interest. It was found that extrusion which of course is conducted at relatively high temperatures, improves the rupture behavior (of the 33 Ni-21 Cr-bal Fe alloy) to values approaching those of the solution annealed material even though no significant grain coarsening could be observed. The subsequent medart straightening, an integral part of the processing, appears to add an additional increment of strength particularly at lower temperatures.[32] (Figure 14). The effects of controlled amounts of hot or cold work on elevated temperature behavior have been studied before, but it is of considerable interest and practical value that extremely beneficial and reproducible effects can be obtained through routine and relatively simple processing procedures.

Conclusions

No attempt has been made here to supply specific solutions to specific problems. Such a procedure could result only in an enormous volume of words of only limited applicability to the majority of petroleum and petrochemical producers. Rather the authors have tried to show the interrelation between chemical, physical and mechanical properties in a relatively broad fashion in the hope that, if detailed solutions could not be provided, a better insight into the capabilities of the several types of alloys and the factors involved in the selection of materials for high temperature service would be obtained.

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Any discussion of this article not published above will appear in June, 1961 issue.

Painting of Welds*

By JOHN D. KEANE and JOSEPH BIGOS

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Abstract

In an experimental study by the Steel Structures Painting Council, 1146 welded, treated and painted test specimens were exposed to determine methods of obtaining improved paint performance over the weld areas of steel structures. During 30 months exposure in an industrial atmosphere, the performance of primers and primer-topcoat systems was observed on various types of welds which had been given various surface preparations and pretreatments before being painted. It was found that residues caused by the electrode coating should be removed from the weld area preferably by blast cleaning, before painting. When this is not possible, several types of pretreatments, such as washing with dilute chromic or phosphoric acid followed by a rinse, were helpful. Surprisingly, scrubbing the weld area with plain water was also very effective. The method of paint application had no effect, and there were only relatively small differences in the performance of various commonly used primers during the test period. Some types of welds were more easily painted than others, particularly those which had a minimum of alkaline deposit left by the electrode coating. Smoothness of bead and metallurgical factors appeared to be of minor importance. 5.4.5

Introduction

AS THE WELDING of steel structures comes into more and more prominence, so does the problem of getting the best possible corrosion protection for those welds. Frequently the paint covering a welded area will fail while the remainder of the paint is still in excellent condition. Because of the importance of the problem and the dearth of practical information on the subject, a study of this problem was undertaken three years ago by the Steel Structures Painting Council; this paper is submitted as a report of the research committee on the subject.

MacEwan and Yates[1] cite the work of investigators of the corrosion of steel weldments. The work done on painted welds, however, is limited. Several theories have been offered as probable causes of the observed paint breakdown. Liebman[2] states that failure occurs from loose mill scale, weld oxide, deposits of weld flux (slag), weld spatter and weld fumes rather than residual stress as previously believed. Good paint performance depends upon proper removal of these deposits, either after welding by mechanical and chemical means or by treatment of the weld area with pre-weld oils or anti-spatter compounds before welding.

Vanderpool[3] points out that slag not only prevents good paint adhesion but also, being cathodic to steel, is a source of initial corrosion. The thorough surface preparation required in standard metallizing procedures on welded areas eliminates much of the danger of failure from welding residues. The presence of the anodic metal also keeps the weld area cathodic and non-corrosive.

Brooking[4] recommended physical or chemical cleaning. Adas[5] stresses that metals should be cleaned before welding and that sand blasting is preferred after welding. Karinsky, Kinelski and Gruca[6] show results of controlled atmospheric corrosion tests on spot welds in low alloy, high strength steel. It was found that spot weld sealers and primers had a decided effect in the prevention of corrosion cracking. Articles by Hammond,[7] Wise[8] and Campbell[9] all point out that proper cleaning to remove weld deposits is mandatory for good paint performance.

Since adhering weld deposits are among the main causes of paint failure, it seems advisable to investigate their source. Spraragen and Clausson[10] outline the purposes, composition, and by-products of the coatings and fluxes used in the weld of steel. The purposes are: (1) to provide a protective reducing atmosphere; (2) to stabilize the arc; (3) to provide a slag of suitable characteristics to protect the molten metal without contaminating the weld; (4) to add alloy elements to the weld metals.

Welding rod coatings are divided generaliy into flux coatings (sodium and calcium compounds), slag coatings (mainly silica and silicates) and mixed organic-inorganic types. Slag forms across the surface of the molten metal and presents a protective shield against oxidation. Constituents are added to the coating to stabilize the arc. It is apparent, of course, that although these coatings and fluxes may form undesirable products on the surface of the weld from the corrosion and painting point of view, their inclusion in a welding process is necessary to insure desirable characteristics in the weld metal.

Kugler[11] believed that the use of low hydrogen electrodes prevents the delayed flaking of the enamel on structural steel panels. Lime and titanium dioxide coatings are used on electrodes for depositing low hydrogen weld metal and preventing the evolution of hydrogen from the weld coating. Henry and Clausson[12] give the compositions of electrode coatings in the welding of steel.

Brooking[4] states that the preparation of welded machinery for the first coat of paint automatically sets the standard for the paint life of the machine. If the first coat breaks down, successive coatings are short-lived unless the first is completely removed—a costly and time consuming process. Both physical and chemical cleaning are necessary to remove insoluble deposits and also alkaline residues.

Jacobson[13] and an anonymous article[14] advocate the use of blast cleaning as the quickest and most economical method of cleaning welds. Blast cleaning with sand or grit, where the abrasive material is propelled by high pressure air, is recommended for large structures; centrifugal blast cleaning in an enclosed booth is recommended for small parts prior to painting.

Preliminary Accelerated Tests

In order to determine the most important factors in painting over welds, a series of accelerated tests were conducted to decide, (1) the electrode types to be used; (2) pre-weld treatments; (3) post-weld treatments and (4) the design of the test specimen. These were required to lend themselves to experimental study and still represent materials and methods used in actual practice.

Electrode Types

Ten types of electrodes have been classified by the ASTM for use on mild steel. Of these, the eight listed in Table 1 were considered suitable for testing. In the preliminary work, one specimen of a T-fillet weld type was made for each of the electrode types. The weld areas on all of the specimens showed a high alkalinity, above pH 12 in litmus paper tests with the exception of E6010 (low hydrogen electrode). Each was hand chipped and wire brushed for a standard period of time to remove adherent weld slag and spatter as described in Section 3.5 of SSPC-SP-2-52T, "Hand Cleaning." Half of each specimen was then brush painted with a standard red lead-linseed oil primer and the other half with a zinc chromate structural steel

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TABLE 1—Electrode Classification*

Designation	Specified Composition	Current
E 6010.....	High Cellulose, Sodium	DC Reverse
E 6011.....	High Cellulose, Potassium	AC, DC Reverse
E 6012.....	High Titanium, Sodium	DC Straight
E 6013.....	High Titanium, Patassium	AC, DC Straight
E 6016.....	Low Hydrogen, Potassium	AC, DC Reverse
E 6020.....	Iron Oxide	AC, DC Straight
E 6024.....	Iron Powder, Titanium	AC, DC Straight
E 6027.....	Iron Powder, Iron Oxide	DC Straight

* From ASTM Standard Spec. A 233-55T.

primer. Each specimen was cut in half after drying. One part was tested in a high humidity cabinet and the other in a salt spray cabinet. Three successive ratings of these electrode-type specimens showed no appreciable difference in rate of paint failure and no correlation between rate of rusting and amount of alkalinity of the weld area.

A duplicate test was conducted with essentially the same results, there being no appreciable difference in the paint performance of different specimens in the same environment. The rusting in these accelerated tests appeared to be proportional to the amounts of spatter under the paint. The amount of spatter depended, not only on the electrode type used, but on the anti-spatter compound, the technique of the welder and the amount of cleaning performed after welding. In general, when the other variables were held constant, electrode type E6010 (high cellulose, sodium), produced the most spatter. This electrode and type E6024 (iron powder, titanium) which was reported to cause considerable commercial paint difficulty, are used very frequently for general purpose welding; they were selected as the electrodes to be used in further studies.

Accelerated Tests of Pre-Weld Treatments

To prevent or reduce the adhesion of metal spatter in welding, a considerable variety of proprietary anti-spatter compounds are available for application prior to welding. Table 2 shows results of preliminary testing. These compounds effectively reduce the time required for cleaning a weld, but also produce a surface of unknown effect on the paint. A preliminary test was conducted to determine if such materials would aid in the cleaning of welds and also serve as good bases for paint. The purpose of this preliminary work was to find substances that combine the properties of good anti-spatter compounds with the ability to provide a good surface for paint adhesion. There were 23 treatments, including 12 proprietary anti-spatter compounds in this series; the latter were applied to 12-inch long angle irons prior to application of weld beads, made with the E6010 type electrode in the angles. Two additional specimens welded without any anti-spatter coatings were used as controls. During the welding process, the weldability of these various coatings (ability to strike an arc, etc.) was evaluated and all were adjudged satisfactory. Each specimen was hand chipped and wire brushed in a standard way until it was considered suitable for painting. Records were kept of the cleaning time required for each type of treated specimen. Specimens were spray primed to an equal paint film thickness and given three days' exposure in both salt spray and humidity cabinets, after which they were rated for corrosion, adhesion and blistering.

TABLE 2—Results of Preliminary Accelerated Tests of Anti-Spatter Compounds[1]

Code	Treatment	RATINGS				
			Adhesion			
		Rusting	Salt Spray	Humidity	Blister	Total
P	Zinc dust silicone primer	9	10	8	10	37
N	Wash primer WPI	7	9	8	9	33
M	Proprietary phosphate sol.	7	8	8	9	32
O	Lead Chromate wash primer	6	8	8	9	31
S	Boiled linseed oil/min'l spirits 50/50	6	8	8	9	31
U	TT-P-636b primer	6	8	8	9	31
T	Phenolic varnish	4	8	9	8	29
G	Proprietary anti-spatter comp.	6	6	8	9	29
V	Proprietary anti-spatter comp.	6	6	8	8	28
H	Proprietary anti-spatter comp.	6	6	6	9	27
R	Penetrating oil pretreatment	5	8	6	8	27
Control No. 1	Nothing	5	6	6	8	25
Control No. 2	Nothing	5	6	6	8	25
J	Petroleum resin base comp.	..	3	8	8	25
Q	TT-P-86a, Type III primer	7	8	0	7	22
D	Proprietary anti-spatter comp.	6	6	0	9	21
W	JAN-P-735 primer	6	6	0	8	20
A	Proprietary anti-spatter comp.	5	0	6	8	19
B	Proprietary anti-spatter comp.	5	0	6	8	19
E	Proprietary anti-spatter comp.	5	6	0	8	19
K	Petroleum resin base comp.	4	0	6	8	18
F	Proprietary anti-spatter comp.	6	0	0	9	15
C	Proprietary anti-spatter comp.	6	0	0	8	14
I	Proprietary anti-spatter comp.	7	0	0	7	14
L	Proprietary anti-spatter comp.	5	0	0	7	12

[1] Maximum rating—10 points in each test or 40 total for perfect performance.

TABLE 3—Results of Preliminary Accelerated Tests* of Post-Weld Chemical Treatments (Salt Spray Cabinet)

Treatment	RUSTING		ADHESION		Average
	No. 1	No. 2	No. 1	No. 2	
H_2O—Water	6	7.3	6	3	5.5
HCl—Hydrochloric Acid	7	6	8	7.3	7.1
H_3PO_4—Phosphoric Acid	8	8.2	7	6	7.3
H_2SO_4—Sulfuric Acid	7	5.3	8	6.7	6.7
MIL-C-10578 A Type I Cold Phosphate	8	9	8	10	8.8
CrO_3—Chromic Acid	9	9.5	9	8.8	9.1

* First set exposed 2 days and second set 3 days.

The non-proprietary formulations of primers, wetting oils, varnishes, etc. were consistently superior to most proprietary anti-spatter compounds in promoting paint adhesion and preventing corrosion and blistering. Outstanding in these characteristics was a zinc-dust paint (P) that served not only as a good deterent to the adhesion of weld spatter, but also provided an excellent base for paint. (The effect of zinc on weld strength was not evaluated.)

While these findings cannot be considered conclusive, they would seem to indicate that anti-spatter compound loses its universal value if it provides only for easy removal of spatter and not for good adhesion of paint. In this respect, primers, wetting oils, varnishes, etc. may serve both functions satisfactorily. For this reason, most anti-spatter compounds were discarded as treatments of a weld area because they did not improve, but actually detracted from the paint performance. The seven compounds having the best results in this preliminary evaluation of pre-weld treatments were retained for more detailed study.

Accelerated Tests of Post-Weld Treatments

Chemical treatment of the welded steel, after welding and before painting, is sometimes used as a method of inhibiting corrosion and improving paint performance. In order to obtain a preliminary evaluation of post-weld treatments, specimens welded with E6010 electrodes were hand cleaned and washed with equal volumes of one of five pretreatment solutions. These included: 5 percent hydrochloric acid; 5 percent phosphoric acid; 5 percent sulfuric acid; cold phosphate per Military Specification MIL-C-10578A, Type 1,* and 1.6 percent chromic acid. A specimen treated with water only was used as a control. Each specimen was then rinsed with an equal volume of water, blown dry with compressed air, and spray painted to equal dry film thicknesses with the same primer. After priming, specimens were allowed to dry for 24 hours and were placed in a salt spray cabinet for two days. A second set was exposed in the salt cabinet for three days.

* See SSPC-PT2-53T. "Cold Phosphate Surface Treatment."

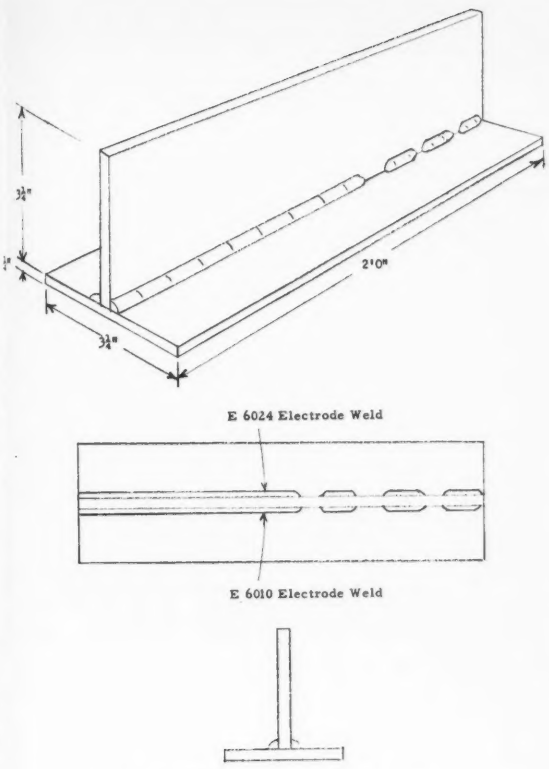

Figure 1—Test specimen—painting of welds.

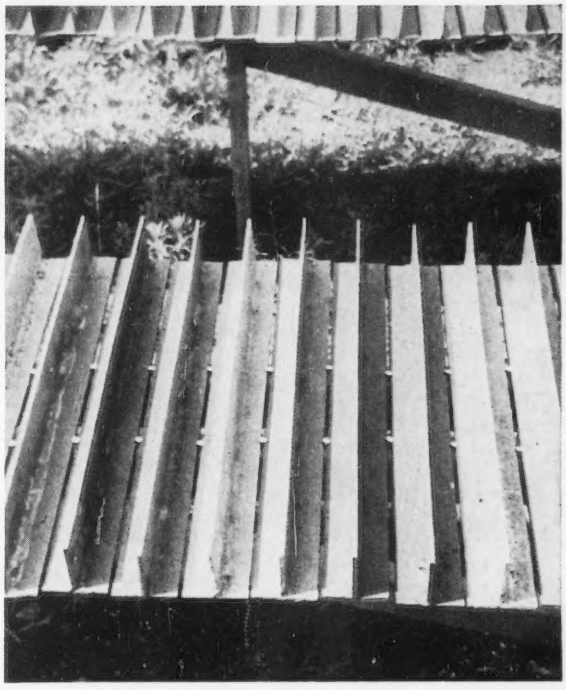

Figure 2—Section of exposure test (before topcoating).

All solution-treated specimens showed improved paint adhesion over the control (water-washed) specimens and slightly less rusting than the control (Table 3). Outstanding in both ratings were those treated with MIL-C-10578A, Type 1, cold phosphate metal conditioner and those treated with chromic acid solution. A repetition of this test showed the same results. From these tests, it appeared that any solution which tended to neutralize the alkalinity of the weld area may aid in the adhesion of the paint film. The superiority of the chromic acid and the MIL-C-10578A, cold phosphate to other acid solutions is attributed to their rust inhibitive properties.

Because of the importance of these findings, it was decided to re-test all of the treatments and anti-spatter compounds. The most promising ones were included in the main outdoor exposure test series. The less promising ones were included in a branch outdoor exposure test accompanying the main series, but in limited combinations.

Preparation of Outdoor Exposure Test Specimens

After the preceding accelerated tests had indicated suitable test procedures and treatments, the preparation of specimens for large scale outdoor exposure was begun.

The main test specimen was of the T-joint fillet-weld type, as shown in Figure 1, because it is representative of the type of weld used in structural work and is also the type that is difficult to protect. The mild, low-carbon, hot-rolled steel used consisted of twenty-five hundred bars, ¼ inch by 3¼ inches by 24 inches of HRC-1020 MBQ. A composition analysis showed 0.21 percent carbon, 0.59 percent manganese, 0.011 percent phosphorous, 0.030 percent sulfur, 0.116 percent copper, and 0.048 percent nickel.

The vertical overhead of 3 inches was used to better receive part of the weld fumes normally deposited when welding in the horizontal position. A bar thickness of ¼ inch is representative of structural steel. A length of 24 inches was established to provide a continuous weld of 12 inches and an intermittent weld of 12 inches on either side of the tee.

The general scheme of the test plan was as follows. For each of the 40 principal weld treatments, 24 specimens were prepared. Twelve of these were primed by brush application and the other twelve by spray. Of these 12, four were hand cleaned, four were power wire brushed, and the remaining four were sand blasted. Each sub-set of four contained one specimen primed with each of four typical structural steel primers.

The sequence of operations was (1) application of anti-spatter compounds to those plates which were to receive pre-weld treatments, (2) welding of the specimens, (3) mechanical surface preparation, (4) post-weld treatment of the specimens specified for this treatment, drying, (5) priming—one coat and exposing outdoors for three months before (6) topcoating with one coat of finish paint on the center half of each specimen.

TABLE 4—Paints Used in Weld Painting Test*

A. Main Portion of Tests

Paint	Description
TT-P-86a, Type I (Primer No. 1)	Red lead—raw linseed oil.
SSPC-2-55T (Primer No. 2)	Red lead-iron oxide—raw linseed oil—alkyd.
SSPC-11-55T (Primer No. 3)	Red iron oxide—zinc chromate—raw linseed oil—alkyd.
SSPC-13-55T (Primer No. 4)	Iron oxide—tung oil ester—gum varnish plus others.
SSPC-Paint 101-55T (TOPCOAT)	Aluminum long oil alkyd.

B. Branch Test Paints

CSA 525	Zinc dust—Zinc oxide primer.
TT-P-64 lb., Type I Chlorinated Rubber	Zinc dust primer. Red lead—chlorinated rubber.
MIL-P-15929 A	WPI and red lead vinyl primer.
Epoxy	Epoxy primer.

Anti-spatter compositions and primers found to be superior in the preliminary tests were brush applied to a sufficient number of plates prior to welding to provide 24 specimens for each of the seven best compounds. Next, 250 specimens (Figure 1) were welded at the Schwab Vocational School, Homestead, Pennsylvania.

After the specimens were welded, they were transferred to Mellon Institute for surface preparation, post-weld treatment (where specified), and painting. Three methods of surface preparation were employed: one-third were hand cleaned in accordance with SSPC-SP2-52T, one-

Figure 3—View of test area, Neville Island, Pa.

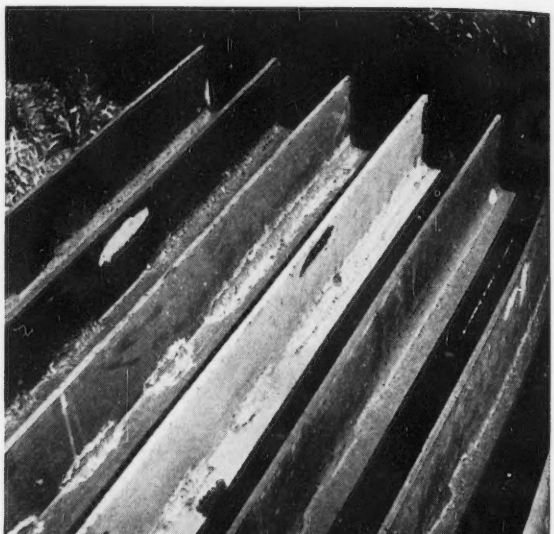

Figure 4—Painted weld specimens after three months exposure, showing incipient whitening of area adjacent to welds on specimens (3 and 4 from left).

third were power tool cleaned in accordance with SSPC-SP3-52T and the remaining one-third were sand blasted in accordance with SSPC-SP6-52T.

Hand cleaning consisted of removing slag and weld spatter with chipping hammers for three minutes per specimen followed by two minutes of hand wire brushing. Power tool cleaning was accomplished by hand chipping followed by two minutes of power wire brushing per specimen. Sand blasting was performed using Ottowa Silica Sand (OSS) abrasive in accordance with SSPC-SPG-52T, "Commercial Blast Cleaning" practice.

Seven sets of 24 panels each had been given the special pre-weld treatments. Of the remaining 33 sets, three sets were to be used as controls, not treated, either before or after welding. One set was washed with water after surface preparation, and the remaining 29 sets were given post-weld chemical treatments shortly after surface preparation.

Next, the specimens were divided into four groups and primed with the following four structural steel primers:

1. TT-P-86a, Type I, a red lead linseed oil Federal Specifications primer.

2. SSPC-Paint 2-55T, a red lead iron oxide linseed oil and alkyd vehicle primer.

3. SSPC-Paint 11-55T, zinc chromate, iron oxide linseed oil alkyd vehicle primer.

4. SSPC-Paint 13, a low cost, quick drying structural steel primer.

These paints, together with others used in the test, are listed in Table 4.

The specimens in this main test totaled 960 in number and provided a method of evaluating two application methods, three surface preparations, four primers, and 40 weld treatments.

Preparation of Branch Groups

In addition to the main group evaluation, specimens were welded in five branch groups to determine the effect of:

1. Electrode manufacturer differences
2. Electrode composition differences
3. Additional anti-spatter compounds
4. Other surface preparations
5. Other primers

Electrodes from 10 manufacturers were used to weld the same type of specimen as used in the main test, except that both sides of the specimen were welded with the same electrode type—E6010 or E6024. After welding, each was hand chipped and wire brushed for a standard time, then painted with one of the 4 primers.

The eight types of electrodes listed in Table 1 (all except one from the same manufacturer)—were used to prepare specimens welded on both sides. Four specimens were made for each type of electrode. These were hand cleaned and brush painted as in the other branch groups.

As noted, 15 proprietary anti-spatter compounds which had not been included in the main group were applied to specimens in duplicate before welding. These were hand cleaned and painted with SSPC primers 11 and 13.

To evaluate surface preparations other than those included in the main body of the project, specimens were welded and hand chipped to remove slag; four replicates of each were further treated by one of the following methods: flame cleaning, pickling in sulfuric acid, then in phosphoric acid.

The fifth branch group was introduced to evaluate the effect of primer types not included in the main body of the test. Specimens were hand cleaned and four of each were wire brushed with one of the following primers: red lead chlorinated rubber, wash primer plus red lead vinyl, epoxy primer, zinc dust—zinc oxide-primer, zinc rich primer.

The welding of specimens was completed on October 15th, 1956, and final painting was completed December 17th, 1956. After inside storage for three months in a relatively dry atmosphere in Mellon Institute, specimens were exposed in a horizontal position in the industrial atmosphere at Pittsburgh in May 1957 (Figure 2 and 3.)

Following a normal three month outdoor weathering of the primer, half of each specimen was topcoated with SSPC-Paint 101-55T "Aluminum Alkyd Paint" in August, 1957 to simulate field exposure of the shop coat and subsequent field painting.

Discussion of Results

Periodic numerical rating of specimens was conducted in accordance with ASTM designation D610-43. Independent ratings were made at various times by members of the task force of the Research Committee, and good numerical agreement was obtained. Specimens were rated after three months outdoor exposure, six months, nine months, 15 months, and 28 months.

A rating of 10 was given to a paint film which had not deteriorated from its initial condition. A rating of 8 was agreed to represent a weld which would require spot cleaning of rust and retouching; a rating of 6 indicated a paint film over the weld area which would require almost complete removal and repainting in order to continue to provide satisfactory protection. The criteria are essentially consistent with ASTM designation D610-43, "Evaluating the resistance to

TABLE 5—Effect of Surface Preparation on the Performance of Paint Over Welds[1]

Surface Preparation	PRIMER ONLY		PRIMER & TOPCOAT		Average
	E6010	E6024	E6010	E6024	
Hand Cleaned	6.5	6.9	8.0	8.8	7.5
Power Wire Brush	6.8	7.1	8.4	9.0	7.9
Sand Blast	7.8	8.1	9.4	9.7	8.8

[1] Each rating represents the average of 320 samples—15 months exposure.
ASTM rating designation D610-43, where 10 = perfect and 0 = complete failure.

rusting obtained with paint on iron or steel surfaces—Type 1—rusting not accompanied by blistering."

An analysis of the variance indicated that the number of specimens was quite sufficient even if there were a first or second degree of interaction among the primary variables. This conclusion was borne out by the results of the test. For example, statistical analysis shows less than a 4 percent likelihood that the difference in averages between two chemical treatments could be due to chance variations. Similarly there is considerably less than a 1 percent likelihood that average differences between any two surface preparation methods could be due to chance. The degree of certitude in comparing paints, application methods and electrodes in the main test is even higher.

After only three months exposure, marked differences were already apparent among the specimens as a result of their differences in surface preparation, pretreatment and primer composition (Figure 4). A progress report written at that time did not differ radically in many of its conclusions from the present report. It was found, however, that the most representative differences were apparent in the primer coat at the 15 month inspection. For this reason, the conclusions in this report are based primarily on a 15 month outdoor exposure, twelve months after the topcoat had been applied to half of each specimen. These conclusions are valid however for the entire 28 month exposure.

Each inspection included a numerical rating of the two weld areas on each specimen for the primer alone and for the primer-topcoat system. The principal results of the 15 month inspection have been summarized in Tables 5 through 13. Some of the conclusions which may be drawn are as follows.

1. *Surface Preparation.* As illustrated in Table 5, the type of mechanical surface preparation after welding is important; each rating shown in this table represents the average rating of 320 test welds. A typical two-coat system kept the weld area in excellent condition during the entire period over a sand blasted weld area, but the same system over a wire brushed surface already required repainting. Frequently, primers applied over welds in the fabricating shops are left for many months before field painting is applied. In such cases, this test shows that the permissible exposure period can be extended considerably by sand blasting of the weld area before painting.

Analysis of the data shows that there is considerably less than a 1 percent probability that the difference in average rating between any two surface preparation methods could be due to chance variations.

The effect of surface preparation was pronounced after three months exposure. At that time, 86 of the 960 specimens had shown some deterioration in the weld area. Of these, 64 had been hand cleaned and 22 were power wire brushed, but none of the sand blasted specimens had shown such deterioration.

Table 6 shows the effect of other surface preparation methods on weld areas in a branch test of this experiment. It indicates that pickling is intermediate between power wire brushing and sand blasting, but that better results (or worse) can be obtained, depending on the details of the weld-pickling procedure. Flame cleaning was found to be comparable with power wire brushing in its effectiveness. Individual specimens showed that thorough rinsing is very important after a weld is given a mineral acid wash to avoid retention of acid in crevices near the weld.

2. *Weld Treatments.* Table 7 shows the effect of the various treatments applied either before welding or between mechanical surface preparation and painting. This table is confined to results on hand cleaned and power wire brushed specimens since the effect of weld treatment was less pronounced upon the sand blasted specimens. Each figure in this table represents the average of 16 specimens exposed for 15 months. Note that several of the two-stage treatments effect a substantial improvement in the performance of paint over welds, particularly those compounds based upon chromic acid and phosphoric acid. The only one-stage chemical treatment that was more effective than plain water was chromic acid.

Surprisingly, scrubbing the weld with plain water was almost as effective as the best treatments. This treatment has the advantage of extreme simplicity and it is not dependent upon subsequent rinsing or any other second operation other than drying. For use under field conditions, the addition of a very small amount of phosphate or chromate inhibitor to the water would be desirable, since otherwise trace amounts of rust form.

Note in Table 7 that treatments 1 through 7 are pre-weld treatments and 9 through 40 are post-weld. Numbers 8, 33 and 34 were controls with no treatment.

A number of compounds, while not as effective as a plain water wash, still improve performance. They may be desirable because of advantages in facilitating removal of weld spatter.

TABLE 6—Effect of Other Surface Preparation Methods (Branch 4)

Application	Brush
Treatment	None
Electrode	E 6010
Primer	SSPC—Paint 2-55T

Surface Preparation	Primer	Primer & Topcoat
Flame Cleaned	7.0	8.5
Pickled H_2SO_4 + Rinse	7.1	9.0
Pickled H_2SO_4 + H_3PO_4	7.5	9.3
Hand Cleaned	6.8	7.8
Power Wire Brushed	7.0	8.8
Sand Blasted	8.0	9.8
AVERAGE	7.2	8.9

Statistical evaluation shows that there is at most a 3.5 percent probability that a 0.3 point difference in average rating between any two treatments could be due to chance variations; there is less than 15 percent likelihood for a 0.2 point difference. In comparing the averages of other variables, such as surface preparation, type of paint or application methods, the significance of a few tenths of a point is much greater, as discussed elsewhere in this paper.

Even the best of the pretreatments applied over wire brushed weld areas are not as effective in improving paint performance as sandblasting. Table 8 shows a branch test on 15 additional anti-spatter compounds that had not been promising in the accelerated tests or which had been received too late. This table is based upon 15 months exposure of specimens with primers only. In relative performance of the various treatments, this branch test shows only fair agreement with the accelerated test made earlier.

Tables 7 and 8 indicate that there are certain types of anti-spatter compounds that are injurious to paint performance, even though they may have the advantage of facilitating cleaning of welds.

3. *Paint Composition.* Tables 9 and 10 show the effectiveness of various types of paint in protecting welds against corrosion. It is apparent from Table 9 that, after 15 months exposure, there is no significant difference in the performance of these four types of linseed oil and alkyd paints. During the first six months, SSPC Paints 11 and 13 were significantly superior to TT-P-86a and SSPC Paint 2 in protective value. This difference typically tended to disappear during the subsequent year.

Table 10 illustrates the performance of the other types of paint, each figure representing the average of only four replicate specimens compared with a total of eight controls. This work, based on a limited number of specimens, indicates that there is a small, but real advantage in painting welds with good vinyl, zinc dust, zinc rich, or chlorinated rubber paints. Table 4 gives further description of paints used.

4. *Electrode Composition.* Table 1 describes the electrodes used in this work, representing eight of the ten principal electrodes used for mild steel. Table 11

TABLE 7—Summary of Treatments Used in Order of Performance

System** Number	Name	Description	Average*
23	Proprietary phosphate pretreatment with rinse.	Zinc phosphate pretreatment.	8.8
9	Water	Weld scrubbed with water	8.6
11	Chromic acid—with rinse	5% solution	8.6
13	Phosphoric acid—with rinse	10% solution	8.6
25	MIL-10578 A, Type I—with rinse	Cold phosphate pretreatment	8.6
27	MIL-10578 A, TypeII—with rinse	Cold phosphate pretreatment	8.6
10	Chromic acid—no rinse	5% solution	8.5
21	Proprietary phosphate pretreatment with rinse	Phosphoric acid metal cleaner	8.5
3	Boiled linseed oil—mineral spirits	Equal amounts	8.4
6	Proprietary anti-spatter compound	.....	8.4
7	Proprietary paint	Zinc dust—pigmented silicone primer	8.4
2	Proprietary wash primer	Lead chromate wash primer	8.3
4	TTP-636b primer	Iron oxide—zinc yellow zinc chromate alkyd	8.3
5	Phenolic varnish	.....	8.3
12	Phosphoric acid—no rinse	10% solution	8.2
15	Hydrochloric acid—with rinse	10% solution	8.2
19	Proprietary phosphate pretreatment with rinse	Phosphate type metal conditioner	8.2
20	Proprietary phosphate pretreatment with rinse	Phosphoric acid metal cleaner	8.2
26	MIL-10578 A, Type II no rinse	Cold phosphate pretreatment	8.2
37	JAN-P-735 1 coat of stripe	Alkyd primer pigmented with TiO_2 and zinc chromate	8.2
40	TTP-86a, III	Quick drying alkyd varnish vehicle paint	8.2
24	MIL-10578 A, Type I no rinse	Cold phosphate pretreatment	8.1
38	JAN-P-735—two coats of stripe	Alkyd primer pigmented with TiO_2 and zinc chromate	8.1
8, 33 & 34	Nothing	No Treatment	8.1
1	WPI Wash Primer	Basic zinc chromate vinyl butyral wash-coat (SSPC pretreatment No. 3);	8.0
17	Sulfuric acid—with rinse	10% solution	8.0
22	Proprietary phosphate pretreatment no rinse	Zinc phosphate coating same as 23	8.0
39	TTP-86a, III—two coats of stripe	Quick drying red lead alkyd varnish vehicle paint	8.0
28	WPI Wash primer	Basic zinc chromate vinyl butyral wash-coat (SSPC pretreatment No. 3); MIL C-15328 A or Bureau of Ships formula 117	7.9
32	Strontium chromate wash primer	Contains strontium chromate—basic zinc chromate and dilute phosphoric acid vehicle	7.8
18	Proprietary phosphate pretreatment no rinse	Phosphate type metal conditioner	7.7
31	Proprietary wash primer	.....	7.6
29	Lead chromate wash primer	.....	7.5
30	Chromic phosphate phate wash primer	.....	7.5
35	Clear lacquer—1 coat of stripe	.....	7.4
36	Clear lacquer—2 coats of stripe.	.....	7.3
14	Hydrochloric acid—no rinse	10% solution	6.8
16	Sulfuric acid—no rinse	10% solution	6.0

* Each figure represents average of 96 ratings on 24 sand blasted, hand cleaned, and power brushed specimens, exposed 15 months, each having 2 electrode and primer and primer-topcoat areas.
** Treatments 1 through 7 were applied before welding; 9 through 40 after welding.

gives the test ratings for paint films applied over the two principal electrodes, each rating representing the average of 960 specimens. Throughout this test, there was an easily observable difference between the paints applied over the E6010 and over the E6024 electrodes. During the first three months exposure, the first 77 painted areas to show deterioration were all over the E6010 electrodes. Table 12 represents a branch test conducted on ten types of electrodes, the average for each electrode representing 4 primers applied by brush over hand cleaned welds. The averages of the E6010 and E6011 are lower than the others, due in part to their poorer performance when painted with TT-P-86a, Type I primer.

The paint on the E6024 welds was always similar in appearance and in rating to that over the smooth plate.

As discussed in the introduction of this report, welding electrodes and their coatings are, of course, formulated and selected as a result of many requirements apart from their effect upon corrosion and paint protection. These tests, however, give some interesting indication of how this property might possibly be improved without otherwise affecting the effectiveness of the electrode coating.

At the beginning of this test, it was thought that the controlling factor might be the sharpness of the electrode bead and spatter. The first spots of rust often appeared at those points where the sharp weld metal edges protruded through the paint film, verifying a common experience that very sharp radii of curvature are difficult to cover properly. As the test proceeded, however, the most common paint failures occurred, not at these sharp edges, but rather at the smooth face of the plate, averaging about ½ inch from the weld itself (Figures 2 & 4). The nature of the failure was further elucidated by the fact that significant improvement was obtained by the use of certain chemical treatments, even including washing with water. This seems to indicate that neither weld sharpness nor metallurgical factors such as stress corrosion or grain size are the controlling factors.

It is indicated that alkaline attack of the vehicle is important, but further work would be necessary to show the specific effect of the type and amount of alkaline residues, fume deposits, gases, oxide and slag. E6010 (high in sodium) and E6011 (higher in potassium) are both among the first to cause failures, but E6013 (higher in potassium) was not particularly troublesome. This fact tends to contradict an earlier theory that the more hygroscopic potassium salt residues might be tending to attract moisture and to saponify the oil vehicles.

A separate branch test showed that there were only small differences among the electrodes made by 10 different manufacturers in their effect upon paint performance.

5. *Paint Application Method.* Since half of the panels were painted by brush application and the other half by spray, this series afforded an excellent opportunity to measure the relative performance of these two methods of application over welds, all other factors being equal.

TABLE 8—Effect of Some Other Anti-Spatter Compounds (Pre-Weld)* Upon Performance of Paints Over Welds (Branch 3)

	Application	**Brush**
	Cleaning	**Hand**
	Primers	**SSPC Numbers 11 and 13**
	Electrodes	**E6010 and E6024**
	TREATMENT	**AVERAGE RATING**
	Nothing	6.8
	Water (Post-Weld)	7.8
A.	Proprietary anti-spatter	7.0
B.	Proprietary anti-spatter	7.0
C.	Proprietary anti-spatter	7.0
D.	Proprietary anti-spatter	7.0
E.	Proprietary anti-spatter	7.0
F.	Proprietary anti-spatter	7.0
G.	Proprietary anti-spatter	7.0
H.	Proprietary anti-spatter	5.5
I.	Proprietary anti-spatter	7.0
J.	Petroleum resin base compound	7.0
K.	Petroleum resin base compound	7.0
L.	Proprietary anti-spatter	7.0
M.	Proprietary phosphate solution	6.5
N.	Wash Primer (WPI)	5.5
O.	Lead Chromate Wash Primer	6.8
P.	Zinc dust silicone primer	7.5
Q.	TT-P-86a, Type III (Post-Weld)	6.0
S.	Boiled Linseed oil/Min'l Spirits 50/50	7.8
T.	Phenolic Varnish	7.0
U.	TT-P-636b	7.0
V.	Proprietary anti-spatter	6.8
W.	JAN-P-735 primer (Post-Weld)	5.8
X.	Proprietary anti-spatter	6.8
Y.	Proprietary anti-spatter	7.0
Z.	Proprietary anti-spatter	7.0

* See Table 7 for Post-Weld Treatments.

TABLE 9—Effect of Paint System Over Welds*

Paint System		HAND CLEANED		POWER WIRE BRUSHED		SAND BLASTED		Average
		E6010	E6024	E6010	E6024	E6010	E6024	
Primer Only	TT-P-86a, Type I red lead in oil	6.4	6.9	6.8	7.2	7.6	7.7	7.1
	SSPC—Paint 2 red lead—iron oxide alkyd, oil	6.5	6.9	6.9	7.3	7.8	7.9	7.2
	SSPC—Paint 11 red lead—chromate alkyd, oil	6.7	7.1	6.8	7.2	8.0	8.4	7.4
	SSPC—Paint 13 low cost shop paint	6.4	6.9	6.8	7.2	8.0	8.3	7.3
Primer + Alum. Alkyd Topcoat	TT-P-86a, Type I	8.2	8.7	8.4	9.2	9.5	9.7	8.9
	SSPC—Paint 2	8.1	8.8	8.6	9.1	9.4	9.7	8.9
	SSPC—Paint 11	7.9	9.0	8.3	8.9	9.4	9.6	8.8
	SSPC—Paint 13	7.9	8.7	8.3	8.9	9.4	9.7	8.8

* Each rating represents the average of 80 samples—15 months exposure. 10 = Perfect.

TABLE 10—Some Other Primers Used for Painting Welds (Primers only, Branch 5)

Application	Brush
Cleaning	Hand
Electrode	E 6010
Paint	Average Rating
Chlorinated Rubber*	6.9
Vinyl*	6.9
Epoxy*	6.2
Zinc Rich*	7.0
Zinc Dust—Zinc Oxide*	7.0
TT-P-86a, Type I**	6.0
SSPC—Paint No. 2**	6.5
SSPC—Paint No. 11**	6.5
SSPC—Paint No. 13**	6.5

* Rating represents average of 4 panels. (10 = Perfect Rating).
** Rating represents average of 2 panels. For composition, see Table 4.

TABLE 11—Paint Ratings Over Two Types of Welds

	Without Topcoat	With Topcoat	Average
E 6010 Electrode	7.0	8.6	7.8
E 6024 Electrode	7.4	9.1	8.3
No. of Specimens	960	960	..

Table 13 shows that there is no significant difference between the two, regardless of the method of surface preparation.

6. *Exposure time.* The apparent importance of some factors in this study varied somewhat through the life to date of the paint film. It was shown, however, that the performance of the primer alone is an index, during the early months, of the subsequent performance of the two-coat system. It also appears to be important, where failure may be imminent on a shop-primed weld, to clean, re-touch and top coat the offending weld promptly and thoroughly. This experimental series will be followed carefully throughout the life of the paint films.

TABLE 12—Paint Ratings Over Various Types of Welds (Branch 2)

Primers	TT-P-86a I, SSPC No. 2, 11, 13
Application	Brush
Cleaning	Hand
Electrode	Average
McKay 6010**	6.6
McKay 6011*	6.5
McKay 6012*	7.0
McKay 6013*	7.0
McKay 6016*	7.0
McKay 6020*	7.0
McKay 6024**	7.0
Lincoln 6027*	7.0
Average	6.9

* Each rating represents 4 rated panels.
** Each rating represents 12 rated panels.
10 = Perfect.

TABLE 13—Effect of Application Method on Painting of Welds*

	Brush	Spray
Sand blasted	7.9	7.8
Power brushed	6.7	6.9
Hand brushed	6.4	6.6
Average	7.0	7.1

* Each figure represents average of 160 specimens after 15 months exposure of primer over E 6010 weld.

Conclusion

Further work will be reported, both in the continued observation of this series and in new phases of the problem.

It has been the intent of this work to resolve the best combination of readily available treatments for use on welded areas. To give paint performance comparable with that on a clean, smooth surface, the following factors are important:

1. If possible, prepare weld area by blast cleaning or equivalent after welding.

2. Otherwise, brush scrubbing of the weld surface with water or dilute phosphate or chromate is effective.

3. Certain anti-spatter compounds and simple treatments facilitate spatter removal and help paint performance somewhat; some anti-spatter compounds are detrimental.

4. Paint application method is not an important factor.

5. Selection of primer paint should apparently be made on the same basis as for the remainder of the structural surface.

6. Certain types of welding electrodes made the painting problem much more difficult.

Acknowledgments

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Internal Carburization and Oxidation Of Nickel-Chromium Alloys In Carbon Monoxide Type Atmospheres*

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Abstract

Tests showed that the rate of internal carburization and oxidation of nickel-chromium alloys attains a maximum at 1500 F-1750 F. Attack was slight at 1330 F and 1830 F. The presence of carbon dioxide, water vapor and hydrogen in the carbon monoxide did not significantly affect the rate of penetration. Modified Inconel type alloys resisted carburization and oxidation in all the atmospheres tested. The mechanisms involved are discussed. 3.8.4

Introduction

THE INTERNAL oxidation of nickel-chromium alloys has been the subject of several laboratory investigations. Bucknall and Price[1] reproduced the attack in a marginally oxidizing-reducing atmosphere by periodical injections of oil. They regarded all internal oxidation as being preceded by carburization, the oxygen diffusing through a chromium depleted matrix and oxidizing the chromium carbides.

Spooner, Thomas and Thomassen[2,3] consider carburization irrelevant and described the basic internal oxidation reaction as occurring at oxygen pressures low enough to oxidize the chromium but leaving the nickel in metallic form.

Previous work carried out at this laboratory[4] produced internal oxidation in nickel-chromium alloys by exposure to carbon monoxide at elevated temperatures. The present work was undertaken to study the effect on internal oxidation, of mixtures of carbon monoxide with other gases, to determine the effect of temperature on the rate of attack, and to investigate the range of conditions under which additions of columbium, titanium and silicon are beneficial.

Experimental

Composition of Alloys

The alloys were similar to those used in the previous work[4]; (i.e., nickel-chromium alloys containing a nominal 4, 14 and 20 percent chromium and 6 or 20 percent iron, and nickel-chromium-iron alloys with additions of silicon or columbium). The analyses of the alloys are given in Table 1.

Composition of Gases

Tests were run in both commercial and CP grades of carbon monoxide. Also, tests were run in the CP grade carbon monoxide, mixed with carbon dioxide and with hydrogen. The gases were dried before entering the furnace by passing through calcium chloride and phosphorus pentoxide. Except in experiments with commercial carbon monoxide and with mixtures intended to contain carbon dioxide, the gases were passed through Ascarite to remove carbon dioxide. In experiments to determine the effect of water vapor, the gases were saturated with moisture at room temperature before entering the furnace. This introduced approximately 3 percent water vapor.

By use of a mass spectrometer, an analysis of the gases was made before and after they entered the furnace. The results are given in Table 2. When moisture was present this reacted with the carbon monoxide to form carbon dioxide and hydrogen. Otherwise there was little change in the composition of the gas during passage through the furnace.

Experimental Procedure

The specimens were about 7.5 cm long and 0.3 to 0.4 cm in diameter. Before each experiment they were cleaned by scrubbing with pumice, then degreased in alcohol and ether, and weighed. The specimens were mounted in a cyclindrical holder.[4] This was inserted in the furnace tube, and after purging with argon, the furnace was brought up to temperature. The flow of the test gas was then started and continued at 100 ml per minute for 7 days. After leaving the tube the gas was burnt. Back diffusion of air or burnt gas was prevented by inserting a dibutyl phthalate trap immediately after the furnace tube exit. At the end of a run, the furnace tube was again purged with argon and cooled to room temperature before removing the specimens.

Measurements

After determination of any weight increase, the specimens were cross-sectioned at the mid-length, mounted, and the depth of the internal oxidation and carburization measured by means of a stage micrometer. Any change in magnetic properties or increase in diameter was also noted. These were in qualitative agreement with the depth of internal oxidation. The penetration measurements were more satisfactory for following the attack than weight change because of the possibility of deposition carbon on the specimens, especially at low temperatures. Temperature measurements over the experimental range 1330-1830 F were made using a thermocouple placed in the gas stream adjacent to the specimen holder.

Results

Tests in Dry CP Carbon Monoxide

Table 3 gives the results of experiments in dry CP carbon monoxide. The greatest amount of internal carburization and oxidation was observed at 1510 and 1690 F. A similar effect of temperature was observed in the experiments with gas mixtures. The amount of attack at 1830 F and 1330 F was lower than at the intermediate temperatures.

TABLE 1—Analysis of Materials

Alloy No.	COMPOSITION, PERCENT								
	Ni	Cr	Fe	C	Si	Mn	Ti	Al	Cb + Ta
56	Bal	3.9	0.10	0.03	0.46	0.01	0.13	0.06	....
65	Bal	13.53	0.13	0.02	0.45	0.01	0.08	0.01	....
67	Bal	19.77	0.10	<0.01	0.52	0.01	0.10	0.02	....
2865	Bal	21.74	0.51	0.03	0.42	0.25	0.03	<0.01	....
2	Bal	14.10	5.61	0.04	0.48	0.85	0.13	0.03	....
76	Bal	13.49	5.83	0.05	0.49	0.78	0.11	0.03	....
4	Bal	14.19	20.25	0.03	0.45	0.78	0.11	0.03	....
25	Bal	15.88	5.63	0.02	1.34	0.84	0.07	0.03	....
3009	Bal	15.83	6.91	0.03	0.29	0.18	0.31	0.22	1.96
2014	Bal	15.80	7.68	0.05	0.28	0.34	0.28	0.12	....

★ Submitted for publication April 23, 1960. A paper presented at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.

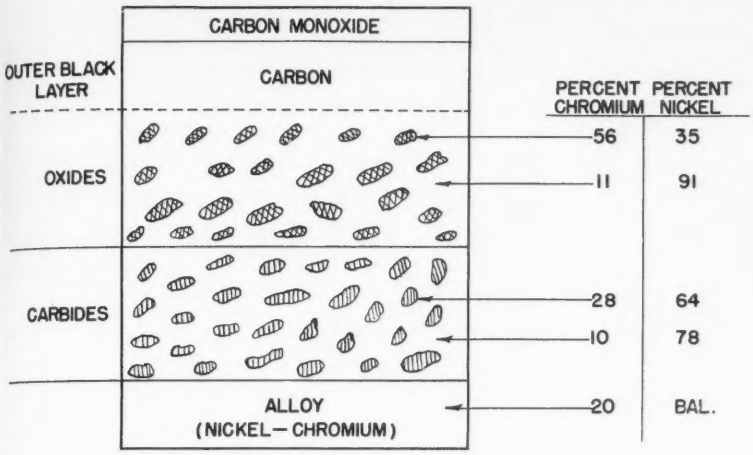

Figure 1—Schematic diagram of analysis by the electron probe micro analyzer.

The maximum depth of internal oxidation in CP carbon monoxide quoted in Table 3 is 2 to 4 mils. This is much less than was shown in the previous work[4] using commercial carbon monoxide when depths as great as 24 and 25 mils were obtained on some of these same alloys in 8 day tests at 1750 F. The commercial carbon monoxide used in these experiments presumably contained some trace impurities that enhanced the attack.

Tests in Commercial Grade Carbon Monoxide

The results of a series of experiments in commercial grade carbon monoxide are given in Table 4. The depth of attack at 1330 F was slightly higher in the commercial grade than in the CP grade. However, at 1510 and 1690 F the carburization and oxidation was slight, but some sulfidation was observed. This sulfur contamination apparently reduced the amount of oxidation, in agreement with observations by others.[1,5] Because of these observed differences in behavior between CP and commercial grade carbon monoxide no further experiments were carried out using commercial grade gas.

Tests in Moist CP Grade Carbon Monoxide

Table 5 gives the results of tests in moist CP grade carbon monoxide. Comparison with Table 3 shows that the presence of water vapor had little effect on the depth of either the oxidation or the carburization.

Tests in Mixtures of Carbon Monoxide and Carbon Dioxide

Table 6 gives the results obtained at 1510 F with 75/25 and 40/60 mixtures of carbon monoxide and carbon dioxide. The addition of carbon dioxide to pure dry carbon monoxide did not influence the rate of attack to any appreciable extent. There may have been a tendency for the depth of oxidation to increase with the addition of carbon dioxide, and for the depth of carburization to decrease. However, the changes observed were small.

Tests in Dry Mixtures of Carbon Monoxide and Hydrogen

Table 7 gives the results obtained at 1510 F with nominal 95/5 and 75/25 mixtures of carbon monoxide and hydrogen. The first test in the 95/5 mixture indicated high rates of internal oxidation, but the depth of carburization was approximately the same as in CP carbon monoxide (Table 3). The rates of internal oxidation were as high as found in the previous work.[4]

Repeat tests in the 95/5 mixture failed to reproduce the high rates of internal oxidation. However, in the test in the 75/25 mixture, high rates of internal oxidation were again obtained. It is clear that even the CP grades of gas mixtures were not giving reproducible results.

Tests in Moist Mixtures of Carbon Monoxide and Hydrogen

The results of tests in moist mixtures of carbon monoxide and hydrogen are given in Table 8. Since these values are similar to the lower two of the three results obtained with dry 95/5 carbon monoxide hydrogen mixtures, it appears

TABLE 2—Analysis of Gas Mixtures

GAS	Temp., °F	ANALYSIS BEFORE FURNACE, PERCENT			ANALYSIS AFTER FURNACE, PERCENT	
		H_2O*	CO_2	H_2	CO_2	H_2
CP grade CO	1510	..	....	....	0.5	<0.1
CP grade CO	1830	..	<0.1	<0.1	0.5	<0.1
Commercial CO	1510	..	<0.1	3	0.4	2.2
Commercial CO	1690	..	0.2	3.3	0.4	2.5
Moist CO	1510	3	<0.1	<0.1	3.3	3.1
Moist CO	1690	3	<0.1	<0.1	1.1	2.4
Moist CO	1830	3	<0.1	<0.1	3.7	2.9
75 CO/25 CO_2	1510	..	26.6	<0.1	26.6	<0.1
40 CO/60 CO_2	1510	..	60	<0.1	60	<0.1
95 CO/5 H_2 Test 1	1510	..	<0.1	5.4	0.4	4.6
95 CO/5 H_2 Test 2	1510	..	<0.1	3.9	....	....
95 CO/5 H_2 Test 3	1510	..	<0.1	3.9	0.4	4.1
75 CO/25 H_2	1510	..	<0.1	21.5	....	....
Moist 95 CO/5 H_2	1510	3	0.1	3.9	3.2	6.6
Moist 95 CO/5 H_2	1830	3	0.1	3.9	3.3	5.6

* No analysis for water was determined. The 3 percent is an estimated value.

TABLE 3—Results of 7 Day Tests in Dry CP Grade Carbon Monoxide

Alloy	COMPOSITION, PERCENT			1330 F			1510 F			1690 F			1830 F		
				Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils	
	Cr	Fe	Other		Carburization	Oxidation		Carburization	Oxidation		Carburization	Oxidation		Carburization	Oxidation
56	4	....	....	21	No Results		166	<1	4	29	<1	2	186	<1	<1
65	14	....	....	117	<1	<1	210	12	2*	51	32	<1	6	<1	<1
67	20	....	....	11	4	<1	17	8	2	33	12	2	20	<1	<1
2865	22	....	....	19	4	<1	250	12	3	10	10	<1	16	<1	<1
2	14	6	....	....	.....	....	....	.....	....	....	.....	....	14	<1	<1
76	14	6	....	....	.....	....	....	.....	....	....	.....	....	11	<1	<1
4	14	20	....	....	.....	....	....	.....	....	....	.....	....	110	18	6
25	16	6	1.3 Si	3	<1	<1	4	<1	<1	11	<1	<1	No Results	<1	<1
3009	16	7	2 Cb	<1	<1	<1	<1	<1	<1	15	<1	<1	43	<1	<1
2014	16	8	0.3 Ti	2	<1	<1	<1	<1	<1	14	<1	<1	29	<1	<1

* Localized attack.

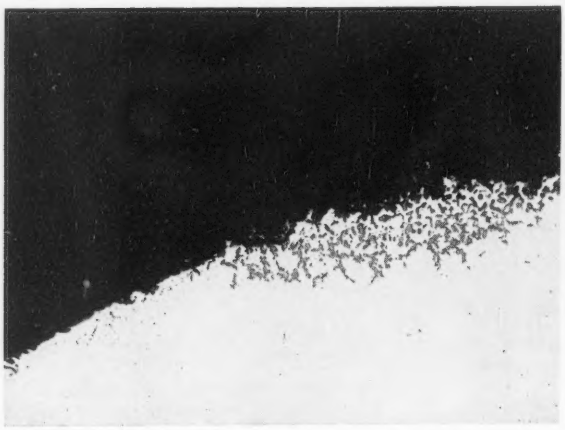

Figure 2—Example of internal oxidation occurring underneath a carbon deposit. Specimen is 86 Ni/14 Cr and was exposed to dry CP grade carbon monoxide at 1510 F for 7 days. Unetched, 250X.

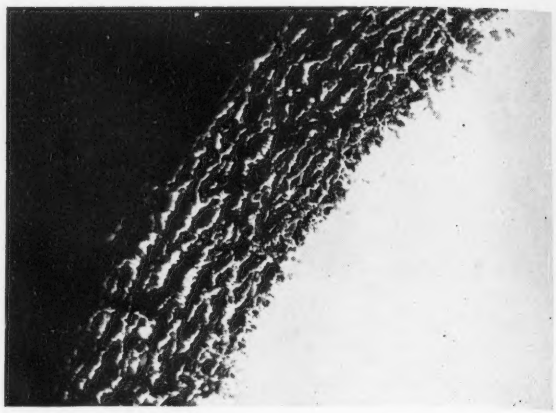

Figure 3—Example of exfoliation which was associated with some carbon deposits. Specimen is 80 Ni/20 Cr and was exposed to dry CP grade carbon monoxide at 1330 F for 7 days. Unetched, 250X.

TABLE 4—Results of 7 Day Tests in Commercial Grade Carbon Monoxide

Alloy	COMPOSITION, PERCENT			1330 F			1510 F			1690 F		
				Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils	
	Cr	Fe	Other		Carburization	Oxidation		Carburization	Oxidation		Carburization	Oxidation
56	4	..	....	477	<1	<1	248	*	<1	255	**	<1
65	14	..	....	405	4	<1	11	*	<1	79	20*	<1
67	20	..	....	33	<1	<1	19	*	<1	14	<1	<1
2865	22	..	....	114	6	2	33	*	<1	10	<1	<1
2	14	6	....	....	....	....	44	*	<1	19	<1	<1
76	14	6	....	....	....	....	30	*	<1	20	<1	<1
4	14	20	....	....	....	....	20	*	<1	151	*	4
25	16	6	1.3 Si	4	<1	<1	14	*	<1	13	<1	<1
3009	16	7	2 Cb	<1	<1	<1	37	*	<1	13	<1	<1
2014	16	8	0.3 Ti	<1	<1	<1	47	*	<1	10	<1	<1

* Sulfidation up to 8 mils deep.
** Localized carburization.

TABLE 5—Results of 7 Day Tests in Moist CP Grade Carbon Monoxide

Alloy	COMPOSITION, PERCENT			1510 F			1690 F			1830 F		
				Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils	
	Cr	Fe	Other		Carburization	Oxidation		Carburization	Oxidation		Carburization	Oxidation
56	4	..	....	150	<1	5	19	<1	3	20	<1	<1
65	14	..	....	87	10	2	66	60	<1	19	<1	5*
67	20	..	....	47	8	3	37	16	3	24	<1	<1
2865	22	..	....	37	8	3	1	<1	<1	10	<1	<1
2	14	6	....	21	8	1	26	12	2	11	<1	<1
76	14	6	....	43	6	1	31	16	2	13	<1	<1
4	14	20	....	27	6	1	50	16	2	11	<1	<1
25	16	6	1.3 Si	13	4*	<1	45	<1	<1	18	<1	<1
3009	16	7	2 Cb	7	<1	<1	6	<1	<1	20	<1	<1
2014	16	8	0.3 Ti	9	<1	<1	7	<1	<1	17	<1	<1

* Localized attack.

that moisture does not increase the rate of attack in carbon monoxide mixtures of this composition.

X-Ray Diffraction Examination of Surface Oxides

The surface oxide developed during exposure in various environments was studied by the X-ray diffraction technique. The results are given in Table 9. The oxides found to be present are hexagonal chromic oxide (Cr_2O_3), chromic oxide with a rhombohedral structure (Cr_2O_3-r) and spinel type mixed oxides. As evident from the table, no significant differences can be seen between various alloys or environments.

Chromium and Nickel Distribution After Internal Oxidation

By utilizing the electron probe microanalyzer it was shown that the oxide and carbides were higher in chromium than the matrix phase. Figure 1 shows a diagrammatic drawing of the oxidation and carburization indicating the observed chromium and nickel levels recorded by the probe. The alloy used for the analysis was an 80 nickel/20 chromium (No. 87) and had been exposed to dry carbon monoxide for 7 days at 1510 F. This alloy remained non-magnetic in the test. These results provide quantitative data in support of the concept of chromium depletion from the matrix, indicated by other workers.

Discussion

Carbon monoxide can decompose according to the reaction

$$2\,CO \rightleftarrows C + CO_2$$

This decomposition is exothermic and

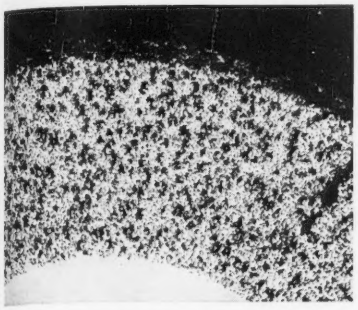

Figure 4—Internal oxidation of 80 Ni/20 Cr alloy in Test 1 of Table 7. Unetched, 100X.

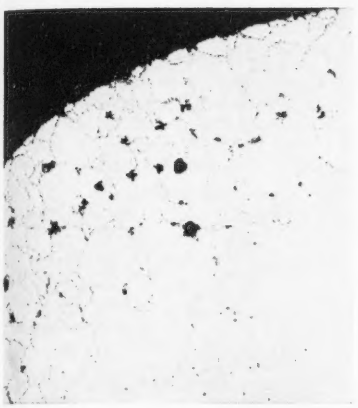

Figure 5—Internal oxidation of 96 Ni/4 Cr alloy in Test 1 of Table 7. Unetched, 100X.

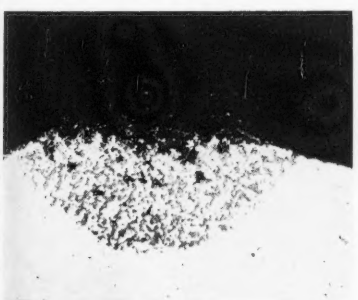

Figure 6—Localized internal oxidation of the 1.3 percent silicon alloy in Test 1 of Table 7. Unetched 250X.

TABLE 6—Results of 7 Day Tests in Carbon Monoxide, Carbon Dioxide Mixtures at 1510 F

Alloy	COMPOSITION, PERCENT			75% CO, 25% CO_2			40% CO, 60% CO_2		
				Gain in Wt. MDD	Penetration, Mils		Gain in Wt. MDD	Penetration, Mils	
	Cr	Fe	Other		Carburization	Oxidation		Carburization	Oxidation
56	4	..	.....	44	<1	13	44	<1	13
65	14	..	.....	17	6	2	157	2	10
67	20	..	.....	17	<1	2*	11	6	2*
2865	22	..	.....	207	6	13	56	2	1*
2	14	6	.....	...	....	....	42	<1	2-4
76	14	6	.....	...	.....	.....	50	<1	5*
4	14	20	.....	...	....	....	31	<1	4-12
25	16	6	1.3 Si	6	4*	2*	9	<1	2
3009	16	7	2 Cb	2	<1	<1	4	<1	<1
2014	16	8	0.3 Ti	4	<1	<1	2	<1	<1

* Localized attack.

the equilibrium quantity of carbon monoxide is raised by increasing the temperature. The actual values for the amount of carbon monoxide in equilibrium with carbon dioxide and carbon at different temperatures is given in Table 10. It is seen from this table that the decomposition decreases fairly rapidly with temperature, from 87.65 percent carbon monoxide at 1470 F to 99 percent at 1830 F. It is suggested therefore that the optimum conditions for internal oxidation require the formation of a gas mixture containing between 3 and 13 percent carbon dioxide. When it is impossible for the carbon monoxide to be dissociated to form more than 1 percent carbon dioxide the internal oxidation becomes negligible.

It is unlikely that equilbrium gas compositions were reached during the present tests. In the first instance the velocity of the gas stream will be a disturbing factor. Secondly, the decomposition of carbon monoxide is susceptible to the presence of catalysts, and although the reaction becomes thermodynamically possible at temperatures below 1832 F it does not take place to a practical extent in the absence of catalysts. Active catalysts either as pure metal, or carbide, are considered essential to achieve anything approaching the equilibrium gas composition.[6]

Catalysts are also significant in the external oxidation of nickel-chromium alloys in carbon monoxide type atmospheres. Lead vapor acts as a good catalyst under some circumstances.[7] On the other hand the presence of sulfur may inhibit internal oxidation.[5]

The high rate of attack observed in two experimental series with carbon monoxide, hydrogen mixtures was probably due to the presence of some catalyst in the gas stream. The catalyst might be some element, such as iron, which was shown by analysis to be present in trace amounts. To further pursue this problem it would be necessary to work with highly purified gases, and to inject catalysts or poisons under closely controlled conditions.

The role of carbon and of carburization in the mechanism of the attack is still not entirely clear. In some instances oxidation was observed only underneath a carbon deposit. An instance of this is shown in Figure 2. (Carburization preceding the oxidation is not visible when the specimen is unetched.) In other cases internal oxidation was observed without any free carbon on the specimens. At the lower temperature (1330 F) heavy carbon deposits were formed, these were associated with an exfoliation type of attack typical of metal dusting.[8] This is shown in Figure 3.

From the results, a number of conclusions can be made regarding the effect of various alloying agents on the resistance to internal oxidation. It was found that the chromium level did not seem to be significant in relation to the depth of oxidation, with the 20, 14 and 4 percent chromium-nickel alloys showing penetration to approximately the same depth under all conditions. The extent of the carburization was also the same for 20 and 14 percent chromium but in the 4 chromium alloy, carburization preceding the oxidation was not observed under any conditions.

TABLE 7—Results of 7 Day Tests in Dry Carbon Monoxide, Hydrogen Mixtures at 1510 F

Alloy	COMPOSITION, PERCENT			95 Percent CO, 5 Percent H_2 Test 1			95 Percent CO, 5 Percent H_2 Test 2			95 Percent CO, 5 Percent H_2 Test 3			75 Percent CO, 25 Percent H_2 Test 4		
				Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils	
	Cr	Fe	Other		Carburization	Oxidation		Carburization	Oxidation		Carburization	Oxidation		Carburization	Oxidation
56	4	..	.....	337	<1	24	141	<1	<1	166	<1	<1	677	<1	32
65	14	..	.....	720	7	22	46	16	<1	31	4	1	1190	12	10
67	20	..	.....	1120	6	28	23	8	2	14	12	2	1530	6	24
2865	22	..	.....	743	6	24	37	10	2	24	10	2	2170	6	24
2	14	6	.....	462	16	6	20	6	<1	11	8	<1	1270	8	10
76	14	6	.....	263	4	8	31	8	<1	16	8	1	1010	4	18
4	14	20	.....	260	3	1	21	6	<1	13	8	1	1140	4	8
25	16	6	1.3 Si	27	4*	2*	10	<1	<1	<1	3	<1	49	4*	6*
3009	16	7	2 Cb	5	<1	<1	6	<1	<1	<1	<1	<1	<1	<1	<1
2014	16	8	0.3 Ti	5	<1	<1	5	<1	<1	<1	<1	<1	3	<1	<1

* Localized attack.

TABLE 8—Results of 7 Day Tests in Moist Carbon Monoxide, Hydrogen Mixtures

Alloy	COMPOSITION, Percent			95 Percent CO, 5 Percent H_2, 1510 F			95 Percent CO, 5 Percent H_2, 1830 F		
				Gain in Wt., MDD	Penetration, Mils		Gain in Wt., MDD	Penetration, Mils	
	Cr	Fe	Other		Carburization	Oxidation		Carburization	Oxidation
56	4	..	.....	176	<1	12	11	<1	<1
65	14	..	.....	190	12	10*	41	<1	<1
67	20	..	.....	46	8	2	19	<1	<1
2865	22	..	.....	41	8	2	4	<1	<1
2	14	6	.....	11	5	4	14	<1	<1
76	14	6	.....	14	10	1	13	<1	<1
4	14	20	.....	10	4	1	11	<1	<1
25	16	6	1.3 Si	6	<1	<1	21	<1	<1
3009	16	7	2 Cb	6	<1	<1	19	<1	<1
2014	16	8	0.3 Ti	2	<1	<1	15	<1	<1

* Localized attack.

TABLE 9—Oxides Indentified by X-Ray Diffraction Techinques

Gas	Temp., °F	ALLOY				
		65	65	2	25	2014
CP grade CO	1510	.....	Cr_2O_3	.....	Spinel	Cr_2O_3-r
CP grade CO	1690	Cr_2O_3, Spinel	Cr_2O_3, Spinel	.....	Spinel	Cr_2O_3-r, Spinel
CP grade CO	1830	Cr_2O_3	Cr_2O_3	Spinel, Cr_2O_3-r	No pattern	Cr_2O_3-r, Spinel
95 CO/5 H_2, Test 1	1510	Cr_2O_3	Cr_2O_3	Cr_2O_3-r, Spinel	Spinel, Cr_2O_3-r	Cr_2O_3-r, Spinel
Moist 95 CO/5 H_2	1510	Cr_2O_3	Cr_2O_3	Cr_2O_3-r, Spinel	Spinel, Cr_2O_3-r	Spinel, Cr_2O_3-r

The type of oxidation at the 20 and 14 chromium levels was as shown in Figure 4. The attack was uniform with no tendency for preferential attack at the grain boundaries. However, the attack on a 4 percent chromium alloy was generally intergranular as shown in Figure 5.

The effect of adding 6 percent iron to a 14 chromium alloy did not cause any pronounced change in the depth of oxidation or carburization in most environments. The only environment in which the presence of 6 percent iron did appear to influence the reaction was in the hydrogen-carbon monoxide mixtures. In Table 7 it will be seen that in Tests 1 and 4 the depth of oxidation was reduced.

Increasing the iron content from 6 to 20 percent caused a tendency for greater cariburization and oxidation at 1830 F in dry CP carbon monoxide as shown in Table 3. This increased carburization and oxidation was not observed if the gas was saturated with water vapor as shown in Table 5.

A 1.3 percent silicon addition to a nominal 14 chromium-6 iron alloy reduced the attack significantly in all environments. However it was not completely immune from attack and Figure 6 shows a typical localized area of oxidation. The beneficial effect of silicon has also been shown by Dovey and Jenkins.[9]

Two alloys did not show any carburization or oxidation under any conditions. These were nominal 14 chromium, 6 iron, balance nickel alloys, numbers 2014 and 3009 with the analysis shown in Table 1. It is known that additions of up to 2 percent columbium help prevent internal oxidation[10] but the composition of alloy 2014 was also apparently sufficient to confer resistance to attack under the test conditions. It is not clear what the mechanism of protection involves but it successfully prevented internal oxidation over the range of temperatures and gas compositions used in these experiments.

TABLE 10—Proportions of Carbon Monoxide in Equilibrium with Carbon Dioxide in the Presence of Carbon at Different Temperatures and Atmospheric Pressure[11]

Temperature, °F	Percent Carbon Monoxide
1292	58.67
1382	75.94
1472	87.65
1562	94.05
1652	97.10
1742	98.77
1832	99.00

Acknowledgments

The authors wish to thank K. G. Carroll for the electron probe microanalysis, J. S. Iwanski for the X-ray diffraction data, and C. P. Venizelos for the gas analysis.

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Any discussion of this article not published above will appear in June, 1961 issue.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Concentration of De-icing Salts In Manhole Waters

NACE TECHNICAL COMMITTEE REPORT

Publication 60–15

A Status Report of NACE Technical Unit Committee T-4D On Corrosion by De-icing Salts★

Abstract

A study was made of seasonal variations in the chloride ion concentration of manhole waters from 25 locations in Buffalo, New York. Eleven of these measurements were made in manholes located at the bottom of inclines where there was a high probability that surface drainage would enter the manhole. Measurements were made of the depth of water in the manhole at the time of sampling, of the pH, the resistivity and the chloride ion concentration. Seven samplings were made over a 3½-year period.

It was found that in most manholes the chloride concentration dropped during the summer although the changes occasionally were small. In three instances, concentration higher than in sea water were observed. 4.6.1

Introduction

IN VIEW of the large rise in the use of de-icing salts on the streets of northern cities and the concern over the corrosion produced by these salts, a task group in Buffalo, New York, undertook a study of the seasonal variations in the chloride concentrations in manhole waters. The task group was interested in the concentration of de-icing salts that accumulated by the end of the de-icing season and in the disappearance or flushing of the salt during the balance of the year.

Testing

Samples were collected from a group of twenty-five manholes located on heavily traveled streets. Eleven of these were at the bottom of inclines where there was a high probability that surface drainage would enter the manhole. Measurements were made of the depth of water in the manhole at the time of sampling of the pH, the resistivity, and the chloride concentration. The depth of water varied from manhole to manhole and with the time of sampling. At the last sampling, eleven manholes had about six inches of water, six had between 14 and 21 inches, and the rest had up to 78 inches of water. The pH range during this sampling was from 7.2 to 9.6 with an average of 7.8.

A plot of the resistivity at this sampling on log log paper against chloride concentration in parts per million is essentially linear and indicates the approximate relationship

$$\rho = C_{Cl}^{-1/2} \cdot 2 \times 10^4$$

where ρ is the resistivity in ohm-centimeters and C_{Cl} is the concentration of chloride ion in parts per million. The measured resistivity varied from 70 ohm-centimeters to 4000.

Buffalo has approximately 641 miles of streets of which 170 miles get 75 percent of the salt used. The other 25 percent is distributed over the remaining 471 miles but in a less uniform manner. A change in salting policy occurred in the 1958-1959 season. Salting is started now when the snow begins to fall and not after it has stopped. The actual amount of salt used under the two systems is as follows:

1955-56	13,000 tons
1956-57	16,000 tons
1957-58	12,627 tons
1958-59	23,500 tons
1959-60	23,000 tons (estimated)

In Figure 1 (see Page 106), the concentration of chloride ion in the various manholes is shown for each of the seven samplings. It will be noted that in most manholes the chloride concentration drops during the summer to fairly low values. In several of the manholes, however, the change is small and the salt concentration remains up during the summer. In three instances, concentrations higher than in sea water were observed.

The sampling is being discontinued but the manhole hardware and cable sheaths will remain under observation for corrosion until definite conclusions can be reached. The variations in the depth of water in the manholes at the time of sampling and during the intervening periods make obesrvations of relative corrosion susceptible to considerable uncertainty.

Acknowledgment

Acknowledgment for this Task Group contribution is made to Messrs. A. Fini, E. K. Benson, and K. G. Compton.

★K. G. Compton, Bell Telephone Laboratories, Inc., Murray Hill, N. J., Chairman.

10-Year Index to Corrosion Magazine

An alphabetical subject and author index of the first 10 years (1945-1954) of CORROSION is available. A chronological table of contents of each issue is included. Write to CORROSION, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

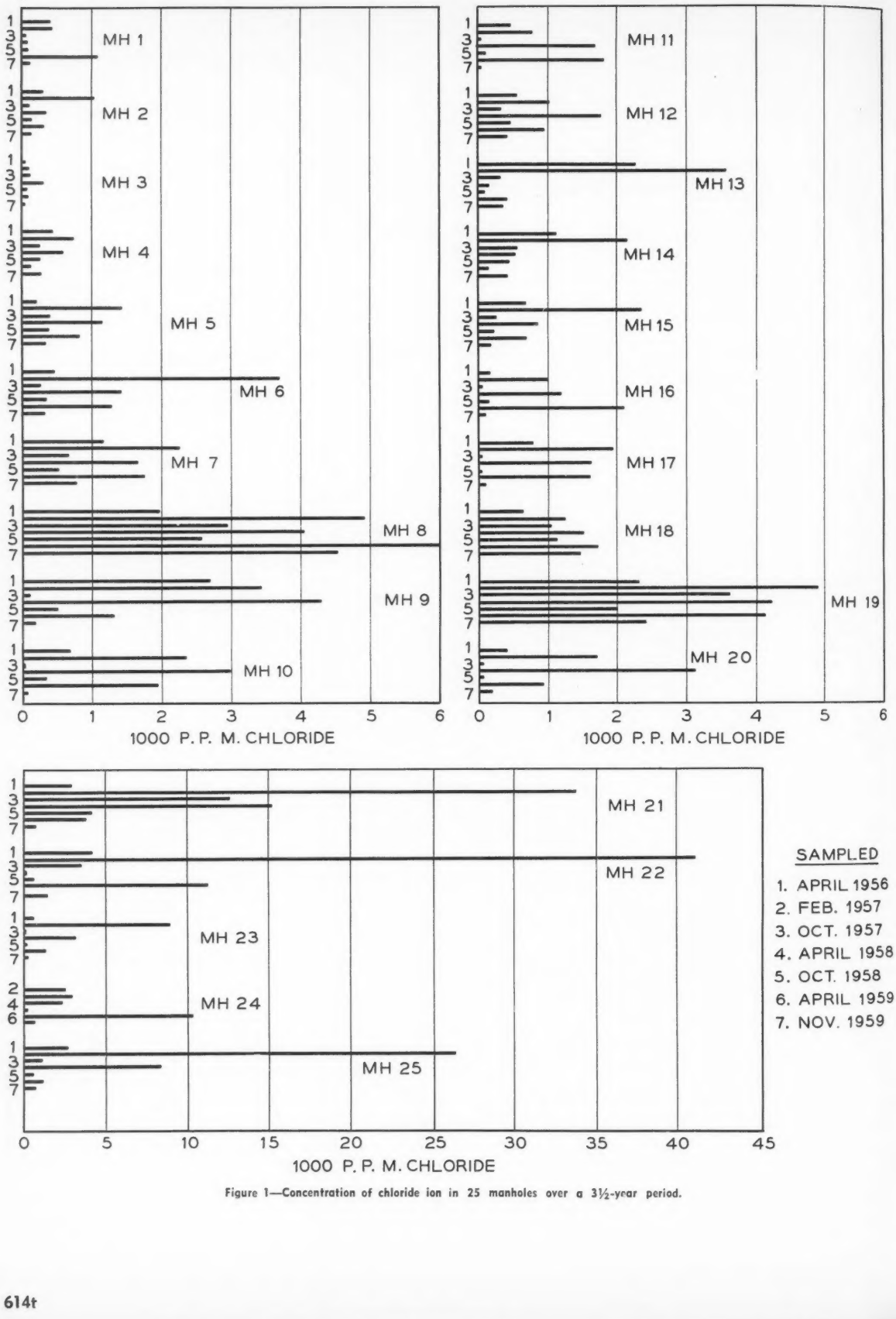

Figure 1—Concentration of chloride ion in 25 manholes over a 3½-year period.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Glass Linings and Vitreous Enamels

NACE TECHNICAL COMMITTEE REPORT

Publication 60–16

A Report of NACE Technical Unit Committee T-6H On Glass Linings and Vitreous Enamels*

Abstract

A detailed account is given of the uses and limitations of glass linings and porcelain (vitreous) enamels for metal structures. The discussion of glass linings goes into such matters as nominal composition of glass, production and preparation procedures, application, metal surface preparation, firing atmosphere, equipment design, hydrogen spalling, thermal shock, etching, abrasion resistance, testing techniques, heat transfer characteristics and repair of glassed steel equipment. Test data reported include the resistance of borosilicate glass to five acids (hydrochloric, nitric, sulfuric, acetic and phosphoric) and to three alkalies (sodium hydroxide, sodium phosphate and sodium carbonate).

Topics discussed in connection with the use of porcelain enamel coatings include production procedures, application, nature of metal substrate, thermal shock, and possible industrial uses. 5.4.2

Forward

NACE TECHNICAL Unit Committee T-6H was organized for the purpose of assembling and disseminating to the corrosion engineer, factual and quantitative data on the performance or limitations of the various inorganic materials that are successfully used in coatings and linings. While every attempt is made to be factual in the coverage of application in chemical resistance tables and physical properties, it nevertheless should be recognized that changes in compounding formulations of inorganic materials or linings enhance or detract from their inherent corrosion-resisting characteristics. Under the circumstances, these reports and recommendation lists must be viewed as showing average properties only. The possibilities of changes in chemical and physical characteristics as produced by various manufacturers or applicators of the material should be kept in mind.

Committee Purpose

Committee T-6H was reactivated for the purpose of preparing a factual report on glass lining and porcelain enamel. In this work, the committee's aim was to include as much relevant technical material as possible so as to be of maximum aid and value to the intended user. Secondly, the report includes up-to-date data of interest to those who are already utilizing glass-lined or porcelain enamel coated equipment or parts.

Glass Lining Technology

Glass Linings

Although alloys and metals are resistant to corrosion by certain chemicals, glass is fully resistant to a great many corrosive environments. For many years, the chemical industry has depended upon glass to combat the extreme corrosion conditions encountered in the laboratory and in production. There are two types of glasses which have the high universal corrosion resistance required by the chemical industry: (1) High silica glass and (2) borosilicate glass. High silica, while being the most acid resistant glass, is very difficult to apply to steel; therefore, the borosilicate glass is the type used in coating most vessels and equipment for severe chemical service.

Normal composition. Borosilicate glasses are combinations of metal oxides from the four groups:

(1) RO_2—silicon, titanium, zirconium oxide

(2) RO—calcium, magnesium

(3) R_2O_3—boron

(4) R_2O—sodium, lithium

Silica is the main glass former and accounts for the major percentage of a glass composition. Zirconium imparts alkali resistance to the glass, and the other oxides act as fluxes in the glass melt. Because silica is fairly soluble in caustic solutions, it is not possible to build as high an alkaline resistance into a glass as it is acid resistance. Cobalt oxide is added to the glass melt to give the resulting blue color; it may be omitted from the melt without impairing the corrosion qualities.

Production of Glass. Compounds such as the oxides, soda ash, borax, lithium fluoride and sodium nitrate are thoroughly dry mixed. This mix is then charged into a glass smelter where it is fused into a molten batch at a temperature of approximately 2500 F. After a specific heating and soaking schedule, the molten glass batch is discharged into a tank of cold water. The sudden chilling of the glass causes it to be severely stressed and shattered into small pieces. Glass in this quenched condition is known as "frit." The frit is dried to remove water and stored in bags or bins ready for processing into the form needed for glass coating steel.

Preparation of Glass for Production. The glass frit is prepared for use in production in two forms: "slip" and "dust."

To prepare slip, the frit is ground in porcelain lined ball mills together with specific amounts of water and such suspending agents as clay. After a period of grinding, a slurry results. This slurry is composed of finely ground glass held in suspension by the clay. By the proper use of water and electrolytes, the specific gravity and viscosity are adjusted to obtain the necessary flow and spraying properties.

Dust is prepared by dry grinding the frit in a ball mill to the required fineness.

Application of Glass. There are three main methods of applying glass to metal: (1) spraying, (2) slushing, and (3) hot-dusting.

1. "Spraying" is the method used to coat large vessels and accessories. The slip is sprayed onto a clean metal surface, allowed to dry, and the item is then placed in a furnace and the coating fused down. Subsequent coats of glass are sprayed over the fired glass surface and fused.

2. "Slushing" consists of either dipping the item to be coated into a container of slip or pouring the slip over the metal surface. By proper adjustment of flow and specific gravity, the desired thickness of glass can be made to adhere to the metal and the excess drained off. The dried coating is then fired in a furnace. This method is most suited for intricate shapes and pipe.

3. "Hot-dusting" consists of shifting glass dust onto a preheated metal surface that has been ground coated. The item is immediately replaced in the furnace and the glass fused down. The process is repeated on the hot item until the

*R. McFarland, Hills-McCanna Co., Chicago, Illinois, Chairman

desired thickness of glass is reached. This method is mainly used on cast iron items, such as valves and fittings.

"Ground coat" is the term given to the first coat of glass which is applied to the metal surface. The purpose of this coat is to form a strong bond to the metal surface and also give a glassy coating to which subsequent cover coats can be fused. The ground coat is formulated specifically for the purpose of promoting adherence to the base metal and is usually not a high corrosion resistant glass.

Even the most corrosion-resistant glasses are attacked, to a slight degree, at a definite rate; for this reason, it is essential that an adequate thickness of glass be applied to the metal to ensure reasonable life expectancy. To obtain this thick glass coating without resorting to many firings of comparatively thin spray coatings, the "spray-dust" method is employed.

With this method, the item is first sprayed with the glass slip. While the slip is still wet, the glass dust is applied to the surface. The water in the slip is partly absorbed by the dry dust, causing the dust to adhere to the surface. In this manner, it is possible to apply coatings of about 0.020 inch thickness per coat.

Metal Surface Preparation. While glass can be formulated to adhere to many metals, commercial processes are restricted to glassing carbon steel, certain high-tensile steels, Inconel, Hastelloy (C, B, F), cast iron and nodular cast iron. Certain stainless steels (e.g., Types 304, 316 and 430) can be glassed successfully, although Types 304 and 316 do not lend themselves to the application of a high test glass. Items made of cast steel do not glass well.

The chemical composition of carbon steel must meet certain specifications if it is to be glassed successfully. The usual steel used in fabricating chemical vessels and accessories is ASTM A-285, Grade A or B flange quality. Although rimmed steel is usually employed, certain killed steels also can be glass coated. It is readily seen that if the base metal is so important in ensuring good glass coatings, the weld must also be very carefully controlled. Special low-hydrogen weld wire must be used wherever the welding is to be glass coated.

After the item has been fabricated and is ready for glassing, it is placed in the furnace, brought up to a temperature of about 1550 F and removed from the furnace to cool in air. This annealing (or normalizing) operation relieves stresses in the metal introduced by welding and fabrication. In addition, the heating cycle burns off any grease or oil on the metal.

The final step in preparing the metal for glassing is to sandblast the surface to be glassed. Sandblasting removes furnace scale and oxide from the metal, and although the adherence of glass to steel is believed to be largely chemical in nature, it is advantageous to roughen the surface of the metal to ensure a good glass-to-steel bond.

Firing. After the spray-dusted or slushed coating is thoroughly dried, the item is placed in a furnace, brought up to the required firing temperature, soaked out, and removed from the furance to cool.

The ground coat is fired at a higher temperature than the cover coats; firing temperature for ground coat is approximately 1600 F, while cover coats are fired at approximately 1500 F. In certain cases, it is desirable to control the furnace atmosphere to prevent rapid oxidation of the base metal by introducing inert gases or products of combustion into the furnace. It is also desirable to keep the dew point of the furnace low to reduce the amount of large bubbles in the glass coating. Between coats of glass, all radii and rough areas on the lining are ground before applying the next coat. This is to prevent an excessive glass build-up on areas which might tend to spall off.

Equipment Design

Because glass is very strong in compression, but weak in tension, the glass is formulated so that it has less thermal expansion than the base metal to which it is applied. Therefore, during the cooling, very high compressive stresses are set up in the glass coating. Sharp edges will not glass well due to the surface tension of the glass, but even edges that are ground with a radius are not suitable if the radius is not generous enough. Glass will tend to shear off of radii that are too sharp. This requirement for curved surfaces and rounded edges results in the necessity for using swaged openings, Vanstone flanges, and flanges on covers and clamp-top vessels.

Jacket aprons and sealers must be so designed that no undue stresses are introduced into the liner shell during welding of the jacket. Excessive heat applied to the liner shell will cause the steel to expand and thus crack the glass by tension stress.

The heating (firing) procedure used in glassing steel must be carefully controlled and for this reason the design of the equipment must be such that there are no sudden changes in metal thicknesses, such as in very heavy flanges, etc.

The base metal must be thick enough to withstand the operating pressures and also to support the vessel from sagging during firing at the elevated temperatures encountered in glassing. The unit must be so designed that any stress, or combinations of stresses occurring during the actual operation of the vessel does not exceed the yield point of the base metal.

Hydrogen in Steel. Steel, when heated, has a very high solubility for hydrogen. Upon cooling, the solubility decreases and absorbed hydrogen must escape. If an attempt is made to glass all sides of a piece of steel, the hydrogen pressure built up at the glass-steel interface will be great enough to pop the glass off of the steel.

The special treatments and steels that have been developed to allow glassing all sides of steel are not economically feasible for use on large chemical reactors. It is this same solubility for hydrogen that makes acid attack on steel very detrimental to glass linings. The hydrogen generated by the acid attack on the outside of a tank diffuses through the steel to the glass-steel interface, where it builds up enough pressure to spall the glass. For this reason, it is essential that good housekeeping be practiced for prolonged service from glass-lined equipment.

From the information given above, it is easily seen why glass lined equipment cannot be electrolytically plated: the hydrogen generated in the process would be detrimental to the glass coating. One acceptable plating method is the electroless nickel-phosphorous process. With the proper caution and technique, it is also possible to flame spray unglassed portions of glass lined equipment with metals, such as aluminum.

Handling of Equipment. During shipment, glass-lined equipment is fastened to skids by means of metal straps or by bolting to shipping legs. It is good practice to keep the equipment on these skids until the vessel has been moved to its final location. Items externally glassed should be shipped completely boxed and properly cushioned. Size permitting, vertical tanks are best handled in the upright position.

It is recommended, when hoisting, that a four-leg bridle sling be attached to the skid under the body of the tank. If it is desired to use choker slings, do not hoist an unjacketed vessel using only one sling as this results in too much load concentration on the vessel. In using two choker slings, it is good practice to distribute the load over a large area. An unjacketed tank should be wrapped with 1 inch x 6 inch wood lagging on the under half of the tank before applying the choker slings. Larger size vessels are shipped with lifting loops welded on. Under no condition should a vessel be lifted by attaching slings to drive supports or nozzles.

Do not weld on any metal that has been glassed. When welding in the vicinity of a glassed surface, be sure to protect the glass from flying sparks and weld spatter. During welding on jackets and other accessories, precautions must be taken to prevent high local heat import.

Glassed Pipe. Pipe connections to glass lined equipment should be made only after the vessel has been leveled and securely fastened to a foundation. To avoid stress failures in glassed pipe, the pipe must be adequately supported by means of pipe hangers and allowance must be made for expansion of the lines if surface temperature is appreciably above room temperature.

Enough pipe hangers must be provided so that the weight of the pipe and its contents are carried by the hangers rather than on the nozzles of the vessel.

The high firing temperatures, plus the stresses introduced by glass coating, tend to distort nozzles on vessels. Likewise, long lengths of pipe tend to bow. The first step in installing pipe is to rotate the pipe or turn it end to end to find

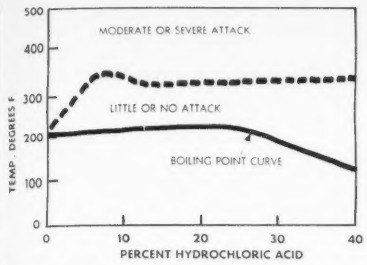

Figure 1—Resistance of alkaline borosilicate glass to hydrochloric acid.

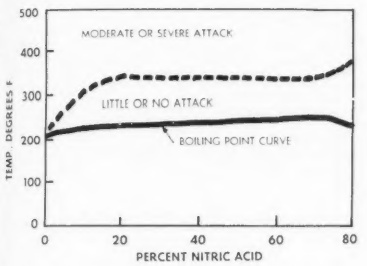

Figure 2—Resistance of alkaline borosilicate glass to nitric acid.

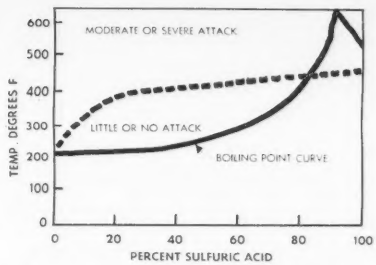

Figure 3—Resistance of alkaline borosilicate glass to sulfuric acid.

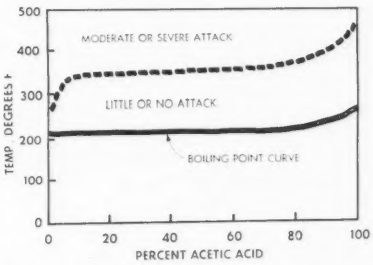

Figure 4—Resistance of alkaline borosilicate glass to acetic acid.

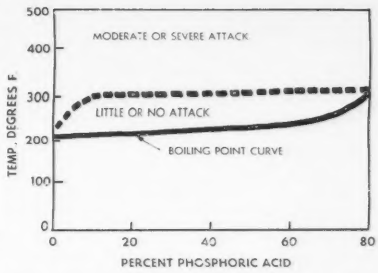

Figure 5—Resistance of alkaline borosilicate glass to phosphoric acid.

the best fit-up. If the alignment is extremely poor, glass lined wedges or porcelain spacers should be employed. Small misalignments can be compensated for by shimming gaskets.

The tightening of split flanges and bolts should be done carefully, evenly, and by means of a torque wrench. Uneven and excessive tightening can cause the glass to spall off of radii. A glassed flange—four bolt or more—should be tightened evenly. It should be tightened with alternately, diametrically opposite "1,3,2,4" tightening of the bolts.

A glass surfaced, flat-faced flange should not be bolted to a raised-face flange because of the hazard of snapping the glassed surface about the fulcrum edge of the raised-face flange.

Gasketing. All glassed flange joints require gaskets. The standard gasket has a combination of hardboard sheet and resilient, semi-hard material enclosed in a Teflon envelope.

Where warpage is such that the joint cannot be easily sealed, the gasket must be built up or shimmed. To properly shim a gasket, the operator should have special instructions as the gasket can easily be damaged.

Where pressures are excessive, shroud rings or metal reinforced gaskets may be installed to keep the gasket from blowing out.

Operation. (1) Vessels designed to operate under pressure are hydrostatically tested internally at design pressures in the jacket at one to one and a half times the design pressure. Operation at pressures in excess of the design pressures can result in extensive glass spalling due to over-stressing the glass.

(2) Glass is very susceptible to damage by mechanical shock. Metal objects, such as steel nuts or bolts, when dropped into a glass lined vessel may cause spalling. Likewise, sharp blows to the outside of the liner shell can cause glass on the inside of the vessel to spall off. Plant aisles for traffic should be guarded adjacent to glass-lined equipment to prevent accidental jarring or tow truck accidents. The glass lining should be well protected when a vessel is entered so as to prevent scratches from shoes and ladders.

(3) The maximum operating temperature of glass lined equipment is determined by the corrosiveness of the materials it will be in contact with. A design temperature of 550 F. means that the vessel can be heated to this temperature under non-corrosive conditions (e.g., in air). The introduction of any product immediately lowers the allowable operating temperature to a point where reasonable life expectancy may be expected from the glass lining.

Thermal shock. Thermal shock is often a cause of failure in glass lined equipment. Suppliers of glass lined equipment furnish charts showing the allowable temperature differentials for safe operation. The service conditions should not exceed those shown on the thermal shock charts if the proper life expectancy is to be obtained from equipment. Any sudden temperature change is a possible source of thermal shock failure. The possibilities are:

1. Introducing a cold charge into a hot vessel.

2. Introducing a hot charge into a cold vessel.

3. Introducing a cold medium into the jacket of a hot reactor.

4. Introducing a hot medium into the jacket of a cold reactor.

While there is a safety factor in the thermal shock curves, exceeding the limit can damage the lining, causing a loss of the batch and possibly the vessel. If it is necessary to operate above the recommended thermal shock limits, or if there is danger of accidentally exceeding the limits, there are high thermal shock resistant glasses available which will resist spalling to a greater extent. These glasses can withstand greater temperature differentials without loss of glass from the steel. It must be mentioned that these very high thermal shock resistant glasses have a lower alkali resistance than the usual glass linings.

Chemical and Physical Resistance

Lining Thickness. Three general types of glass steel equipment are available for corrosion resistance or base metal protection. The types available are: high voltage tested glass linings (thickness of 40 to 80 mils) for very severe corrosive service, low voltage tested glass linings (30 to 50 mils) for mild corrosive service and a "visual" glass lining (15 to 25 mils) used not for its intrinsic corrosion resistance, but to prevent metal ion contamination in polymerization or in handling stored materials.

Acid Resistance. For the lining of chemical reactors and related equipment involving severe service conditions, the 40 to 80 mil glass (alkali borosilicate) is used. While specific formula changes may produce slight changes in chemical resistance, the usual acid corrosion resistance is presented in Figures 1-5. Glass linings of sufficient thickness (40 to 80 mil) possess excellent corrosion resistance to a wide variety of acid environments. All of the common mineral acids with the exception of hydrofluoric acid and hot, concentrated phosphoric acid, may be continuously handled at temperatures of 300 to 350 F, and on occasion, to temperatures as high as 600 F. These very high temperature services should be undertaken only after consulting with the glass lining suppliers. A low molecular weight organic acid, in any concentration, has little or no effect on glassed steel.

Alkaline Resistance. The alkaline resistance of the alkali borosilicate glasses that are used in severe chemical services is shown in Table 1.

The low voltage tested glasses may or may not have the same formulation

TABLE 1—Corrosion Resistance of Glassed Steel to Alkaline Media

Alkali	Concentration, Percent	Temperature, Degrees F	Liquid Phase Corrosion Rate, Mils Per Year
NaOH	1	70	1
		150	5
		210	64
	5	70	1
		150	10
		210	161
	10	70	1
		150	10
		210	175
	20	70	1
		150	22
		210	204
Na_3PO_4	1	70	1
		150	7
		210	40
	5	70	1
		150	9
		210	94
	10	70	1
		150	6
		210	94
	20	70	1
		150	7
		210	79
Na_2CO_3	1	70	1
		150	4
		210	18
	5	70	1
		150	4
		210	29
	10	70	1
		150	4
		210	4
	20	70	1
		150	5
		210	53

as the high voltage tested glasses. Since equipment with this type of coating is intended for mild service conditions, the glasses in general have less average thickness. It is reasonably safe to assume that the foregoing acid and alkali resistance charts apply to the low voltage tested glasses in the temperature range below 125 F. This temperature limitation ensures that there is virtually no attack of the glass.

The so-called "visual" glasses may have thin spots or even exposed steel because of the use of the equipment involved. It is therefore unwise to discuss the corrosion resistance of coatings on such equipment. The chemical limiting factor in the use of this equipment would be the base metal used in the manufacture rather than the coating applied.

Chemical Resistance Limitations. The borosilicate glasses are not resistant to hydrofluoric acid and acid fluoride compounds even in concentrations of a few parts per million. Their resistance to strong alkalis is dependent on temperature. At room temperature practically any alkaline concentration may be safely handled. At the boiling point, concentrations having a pH value between 10 and 12 will cause glass etching on prolonged exposure and for this reason higher pH values are not recommended. Distilled water in excess of 180 F, and steam will dissolve the borosilicate glasses readily; the attack takes place primarily in the vapor phase and in proportion to the temperature.

The above statements are general remarks pertaining to the chemical resistance of the group of glasses used on glass lined equipment. For proposed installations in environments for which data do not exist or in which the use of glassed steel may depend upon the effects of operating cycles, etc., sample glass coated samples should be subjected to the exact conditions desired. Rather accurate quantitative data can be obtained from such tests. The testing techniques are important and those unfamiliar with this type of work would do well to submit samples of their product to the makers of glass lined chemical equipment for evaluation.

Surface Effects (Etching). Because of the highly corrosive conditions and high temperatures to which glassed steel is often subjected, surface effects, such as etching, often occur. The degree of etch present is a rough qualitative measure of the amount of glass corrosion which has occurred. A fine smooth etch is indicative of a relatively small amount of corrosion. A deep rough sandpaper etch indicates a more progressive amount of corrosion.

Abrasion Resistance. The abrasion resistance of the glass used on glass lined equipment varies with the composition of the glass. In general, those glasses used on chemical equipment have more resistance to abrasion than the glasses used for mild service conditions.

While there are several methods of determining the relative abrasion resistance of a glass surface, the method developed for the Porcelain Enamel Institute by the National Bureau of Standards is becoming the recognized standard in the glassed steel industry. The PEI method was specifically designed for ceramic materials and has been developed to the point of excellent reproducibility with a minimum of professional skill required in testing.

Under this method, the chemical equipment glasses show an abrasion range of 48 to 64 (mg weight loss per quarter hour). This compares with a range of 60 to 87 for the glasses used in mild service. The standard of comparison is plate glass which has a figure of 64.3 mgs loss per quarter hour by the PEI method.

Anti-Stick Resistance. The anti-adherence properties of glass have been long recognized. Very few materials adhere to glass and most of the few that do can be easily cleaned off. The widely used expression "as smooth as glass" is an indication that a glass surface is an excellent comparison for anti-adhesion and easy cleanability. Because of its anti-adhesion properties, product purity as well as economical production is more obtainable with glassed steel equipment.

An outstanding example of the use of glassed steel equipment is the plastic industry. Glassed steel reactors are commonly used for both pilot plant and large scale production of a wide variety of polymers. It is not only used for reactors, but for blowndown tanks, storage tanks as well as pipes and valves.

Testing Techniques

Producers—Electrostatic Inspection (Initial). The fact that glass is a good electrical insulator automatically suggests electrical inspection of glass lined equipment. This statement is innocent enough in itself, but may prove disastrous to those not thoroughly versed in the art of applying glass to metal vessels. First, the various glasses applied for different purposes will react differently to the application of high voltage. The thickness of the lining determines the maximum voltage that should be used. Those glass linings that are not guaranteed to be pinhole-free definitely should not be subjected to any voltage.

The second point concerns the type and value of electrical energy used in the applied test on the glass. It is known that repeated high voltage testing even within the dielectric limits of the glass may eventually cause breakdown or puncture.

Variances in the structure of the glass will affect the puncture point of the glass. Such physical factors as frequency, amperage, temperature and humidity have a definite effect on the dielectric strength of insulators at any set voltage. Because of the complexity of electric testing on glass lined equipment, equipment manufacturers' experiences have been combined with theory to set up satisfactory inspection procedures.

All test voltages are stabilized to prevent drifting due to equipment or line fluctuations. (Safety features are incorporated in the voltage supply equipment

to protect the operating personnel and prevent damage to the instruments.)

Twenty thousand volts DC has been set for the value of the test voltage on glass lined chemical equipment. This voltage definitely ensures a minimum sound glass thickness in addition to guaranteeing a continuous glass-lining.

Five thousand volts AC are used to inspect storage vessels where only a minimum thickness of glass is required.

Users—Electrostatic and Visual Inspection (Field). Proper field inspection of glass-lined equipment is very important. If a break in the glass lining can be detected when the flaw is very small, the repair will be much less costly. On the other hand, microscopic breaks do not usually occur under process conditions. Glass failure, whether by mechanical or other means, is nearly always decisive and of a size that may be seen easily with the naked eye.

Inspection of glass-lined equipment therefore becomes a scheduled routine operation, the frequency of which depends upon the severity of the chemicals being processed and the particular method of operation. Visual inspection normally suffices, especially if a satisfactory preventive maintenance schedule is religiously being followed. When unusual circumstances prevail or questionable areas are apparent, some type of electrostatic inspection may be required.

The voltages used in field testing should be the lowest value that will definitely establish the presence of defects in the glass lining. This ensures maximum life from the equipment and substantiates the fact that thin glass is better than no glass at all.

It should be borne in mind at all times that only glass-lined equipment made for severe chemical service should be subjected to field electrostatic tests. All other glasses, because of their minimum thickness requirements, might be severely damaged by such procedure. Stabilized 5000 volt AC of low frequency (60 cycle) has been found to be satisfactory for field testing of glass-lined chemical equipment. The addition of a neon light in the probe handle and the use of various shaped detachable probes will materially shorten the testing time and ensure thorough inspection.

Heat Transfer Through Glassed Steel

Glassed steel is often selected as a barrier material between media during heat transfer processes because of its demonstrated resistance to corrosion and fouling. However, engineers sometimes feel that they are making a substantial sacrifice in heat transfer efficiency when they select glassed steel. Such is not always the case. Under many process conditions, the over-all coefficient of heat transfer for glassed steel is comparable with those of materials having much higher thermal conductivities.

Conductance is not the sole factor controlling the efficiencies of a heat transfer process. Film and fouling resistances as well as the barrier-wall resistance takes a part in determining the over-all coefficient of heat transfer.

When the sum of film coefficients is high, as is usually the case for condensation of a saturated vapor in the absence of a non-condensable gas, then the choice of barrier will materially influence the service coefficient attained in the actual process. The conductance of the barrier wall, in a sense, "controls" the over-all coefficient. On the other hand, for those heat transfer services in which film coefficients are quite low, as in cooling a viscous organic liquid, the influence of the barrier material is negligible. In these instances, the film coefficients control the over-all coefficient.

This is quite fortunate because it is for services involving viscous materials, and those in which corrosion, contamination, and ease of cleaning are of great importance, that glassed steel is most frequently used. In actual processes, the usefulness of glassed steel may be further enhanced because of its marked resistance to fouling and corrosion.

Glassed steel equipment presents a smooth, easy-to-clean surface to the product, thus minimizing adherence. The glass resists corrosion of all acids (except hydrofluoric) at elevated temperatures, and alkalis at moderate temperatures. These properties cannot be quantitatively evaluated or generalized, but experience shows that frequently they more than compensate for the slightly lower service coefficients calculated for glassed steel.

Repair of Glassed Steel Equipment

The type of repair used in glassed steel chemical equipment is usually determined by the chemicals being processed. Other factors, such as (1) size of the damage, (2) location of the damaged area, (3) cost of the repair material, (4) urgency, (5) availability, etc., may have a definite bearing on the choice of the repair material. A combination of one or more of these factors may decide the final choice. An example of this would be an urgent situation where a temporary repair could be used to keep the equipment in operation until a more permanent repair could be fabricated and installed.

Because glassed equipment is unique in its method of fabrication, repair techniques common to other solid materials of construction cannot be used. Repair materials other than glass must be used in such cases, even though they may not have the nearly complete inertness to chemical attack as does the original glass lining. A change in chemical conditions may, therefore, require a change in the repair materials within any given chemical process.

The following guide with chemical and temperature limitations summarizes current practice with regard to glass lined repair materials.

Severe Chemical Service. Temporary repairs consist of cements applied directly to the prepared surface in the form of air drying liquids or putty-like mixtures. Only one group of silicate (or ceramic) cements has been found to have sufficient adhesion for this type of repair. Other cements, such as the furan resin, polyesters, etc., have sufficient chemical and/or temperature limitations, but because of their lack of adherence to glass, should be used in connection with a suitable metal. Thus the latter cements involve permanent rather than temporary repairs.

For maximum adherence and serviceability, the silicate cements require a 24-hour application time including setting and acid treatment. They are resistant only to strong acids and thus should not be used with dilute acids, water or alkaline solutions. The maximum temperature limitation is in the 350-360 F range.

Permanent repairs consist of metal patches in the form of discs, plates, sleeves, caps, boots, etc., held on by means of studs and nuts and separated from the glass by a suitable gasket (usually polytetrafluorethylene). Some suitable cement is necessary to prevent seepage. The metal selected must be satisfactory for the chemical conditions involved. Materials in current use include: (1) tantalum, (2) silver, (3) "Hastelloy" alloys, (4) zirconium, (5) nickel, (6) titanium, (7) molybdenum, and (8) the stainless steels.

The chemical limitations of this second type of repair are necessarily determined by the metal selected. Under the proper mechanical and chemical considerations, such repairs are suitable up to 450 F.

(CAUTION): Two different metals may set up galvanic cells when immersed in the same continuous electrolyte. Abnormal deterioration of one or both of the metals may result.

Mild Chemical Service. Temporary repairs with the silicate cements may be used under mild service conditions if the acidic concentration is suitable. The rather long installation period limits the use of this type of repair for mild services except in emergency situations. Since mild service is normally understood to be less than 125 F, there is no maximum temperature limit for these cements under mild service conditions.

When special techniques are employed, epoxy compounds may be used to repair glass lined equipment under mild service conditions.

Tin alloys for the upper range of temperatures are generally used in the food processing fields. This material also requires special application techniques. For extremely mild services, such as low temperature storage of beer, milk, and other food products, chlorinated rubber paints are being used. The application of this type of repair is very simple and quick to perform. It is used to eliminate rust spots rather than provide any corrosion protection.

Permanent repairs for this service are the same as for severe chemical service, except the gasket may not be used. Generally, the less expensive metals are selected. The temperature of this type of repair is limited by the maximum equipment operating temperature which is usually 125 F.

Gold fillings, installed with dental equipment in much the same way that tooth fillings are made, are quite frequently used where it is undesirable to have a protruding repair. They are not

suitable under strong oxidizing conditions, especially aqua regia. Gold fillings are limited to approximately 125 F because of their expansion characteristics.

When it is desired to exclude all metallic contamination, glassed metal plugs may be used. They are installed with the aid of a facing tool and may be used with or without the gasket. These special plugs are limited to relatively flat surfaces.

Porcelain Enamel Coatings

Definition

Porcelain enamel is defined as a substantially vitreous or glassy inorganic coating bonded to metal by fusion at a temperature above 800 F. In the firing temperature range extending to approximately 1850 F, are numerous commercial formulations having specific physical properties for application to an extensive variety of metal products.

In compounding porcelain enamels, many inorganic materials are used. The selection of ingredients is determined by the base material to which the coating is to be applied and by the end use of the coating. In porcelain enamels for application to steel and most metals, silica, alumina, and the oxides of boron, sodium, potassium are the basic ingredients.

Production

The raw materials are smelted in a special batch of continuous melt furnace at high temperature. When the proper molten state has been attained, the mass is flow quenched in cold water or flowed over water-chilled rolls which shatters it into small fragmented particles called "frit."

In the preparation of "slip" for application by spraying, dipping and flow coating, the frit is finely milled with clay, water, and electrolytes. White and colors are usually produced by including metallic oxides in compounding the melt. Colored porcelain enamels for decorative purposes are frequently made by adding metallic oxides to the mill mixture in the slip preparation.

After application, the base or ground coat is thoroughly dried in an oven before entering the furnace for fusion of the coating. Castings are coated by the slip method, and also by the dry process method in which finely powdered frit is dusted on the preheated casting which is then returned to the furnace for complete maturing of the coating.

Thickness

For some purposes a single coat may be adequate, but in most cases, multiple coatings are necessary to meet the end use requirement of the product. Applications normally average about 4 mils for a single coat and 8 to 10 mils for a two-coat system. Metal thickness is extremely important in determining coating applications. This is to differentiate from glass linings of greater thickness for chemical services.

Metal Substrate

Porcelain enamels can be commercially applied to sheet steel, steel plate, stainless steel, cast iron, cast steel, aluminized steel, sheet aluminum, cast aluminum and copper. Specific coating systems and metal preparation are necessary for each material to assure conformity and intimate bonding of the base metal and ceramic coating. For the coating of sheet-steel fabricated items above the 1500 F range, the use of porcelain enameling-quality steel is essential, as it is low in metalloid content (carbon, manganese, phosphorus, sulfur and silicon).

For fields of industrial application which principally constitute atmospheric corrosion and mild chemical corrosion, coating systems exist for such applications to low carbon steels. These coatings "mature" in the 1500 F range, and are additionally used for anti-sticking, cleanliness and decorative properties. In some situations, the use of other base materials (i.e., aluminum, etc.), may be mandatory. These would require the selection or development of special coating systems.

Porcelain Types

Acid resisting types of porcelain enamels applied to steel in the 1500 F range are well known. These enamels are governed by the Porcelain Enamel Institute specifications (Reference: Bulletin T-8, for Grade AA, A, etc.). Also applicable is the ASTM test, C282-51T. In general, the aforementioned tests include testing for (1) acid resistance entirely satisfactory for that involved in food handling, sanitary hospital ware, and (2) mild acid use in "normal" environments.

Special formulations can be made to resist mildly alkaline conditions to a pH of 9, and others can be compounded to resist the corrosive action of hot water at elevated temperatures (hot water heater linings). Titanium—opacified enamels and acid resisting antimony enamels fall within the Class "A" specification, whereas non-acid resisting enamels, antimony, zirconium, etc., fall into the Class "D" specification. White porcelain enamels for illumination purposes, averaging 87 percent to 91 percent total reflectance, are commercially available. Where complete acid resistance and maximum operating temperature must be mutually selective, then much thicker high silica-borosilicate glass coatings are required.

The hard surfaces of enamel coatings have low coefficients of friction and are highly resistant to abrasion, rating 3½ to 6 on Moh's scale of mineral hardness. Being smooth and impervious to absorption, they minimize product adhesion and clean readily. Porcelain enamels are essentially glassy and are electrically non-conductors with dielectric strength in the range from 100 to 450 volts per mil depending upon composition.

Thermal Shock

Coating systems vary considerably in resistance to thermal shock. Coatings have been formulated to withstand a temperature differential of approximately 450 F. Color, texture, application thickness, and unit design are factors which influence resistance to thermal shock. Not generally known is the fact that porcelain enamels have excellent thermal emission characteristics substantially superior to most metals.

The maximum operating temperature of a coating closely approaches the softening point of the particular coating system. Special ceramic type heat and oxidation resistant coatings have in recent years been developed for the protection of carbon steels from oxidizing in continuous service at a temperature of 1250 F. Similar coatings are being produced for the protection of stainless steels at elevated temperatures to resist oxidation and to retard carbon absorption which tends to promote embrittlement of some stainless steels. Ceramic coatings are thinly applied in thickness from 0.0005 to 0.002.

Uses

Porcelain enamel, as an engineering material, has extended possibilities for product designers, material engineers and chemical enginers. Porcelain enamels have been universally used for many applications and a partial list of such applications follows:

Air conditioner pans
Air conditioner housings
Awning covers
Basins, industrial waste
Basins, shower, etc.
Bath tubs, etc.
Bins, storage
Boards, tanning
Buckets, conveyer
Bowls, shampoo
Bulkheads, ship
Caps, bubble
Chambers, combustion
Chutes, grain and coal, chemical
Cylinders, pump
Dryer linings
Dial and indicating discs
Dispenser finish
Elevator doors and walls
Exhaust, rings and manifolds
Exchangers, heat, commercial evaporators
Extractors
Fireplace flues
Fittings
Freezer linings
Furniture, lawn
Gasoline tanks
Gutters
Heater linings
Hot water heater linings
Hot water flues
Housings, pump
Humidifiers
Incinerator linings
Iron pipe
Jet engine parts
Jets, Army
Lamp linings

Light linings
Liners, thermos
Manifolds
Muffler linings
Mixers, food
Markers, airport
Meters, water
Pipe linings
Pump linings
Roller coatings
Reflector linings
Stack linings
Shaft coating
Seals, pump
Silo linings
Sterilizer linings
Table coatings
Tank linings
Trap linings
Trough linings
Tube linings
Utensil linings
Utensils, cooking
Utensils, serving
Vault linings
Ware, cast iron
Ware, hospital
Ware, kitchen
Waterers, poultry

Porcelain enamels are engineered ceramic coatings that are tailored to meet special functional requirements. In such instances, laboratory development and long range field tests may be necessary. Due to the variance in operational conditions and environments, it is best to test these coatings systems in actual service. Test specimens are available and can be obtained from qualified porcelain enameling sources, so that actual field tests can result in selection of a porcelain coating system that is most applicable.

The properties, characteristics and versatility of porcelain enamels offer designers and engineers opportunities for product, equipment, and process applications. Such applications should be referred to porcelain enameling sources for evaluation. Engineering services, available from porcelain enameling sources, cover project analysis, selection of base material, fabrication design, and welding recommendations, development of applicable coating systems and the production of test units, where necessary, for field evaluation.

Acknowledgment

The authors acknowledge and thank the technical staffs of the Pfaudler Company and the Glascote Company for their assistance and permission to publish technical data. They also acknowledge and thank the Porcelain Enamel Institute, Inc., for the use of material available in their various bulletins. A large amount of engineering material is available on porcelain enamels from the Porcelain Enamel Institute, Inc., Associations Building, 1145-19th Street, N.W., Washington 6, D. C.

Any discussion of this article not published above will appear in June, 1961 issue.

DISCUSSIONS

Stress Corrosion Crack Paths in Alpha Aluminum Bronze in Ammonia and Steam Atmospheres, By J. F. Klement, R. E. Maersch and P. A. Tully. Corrosion, Vol. 15, No. 6, 295t-298t (1959) June.

Comments by P. J. Le Thomas, Centre Technique des Industries de la Fonderie, Paris, France:

It is suggested by the authors that the aluminum atoms segregated at the grain boundaries are chemically attacked and that the alumina film formed is gradually broken down by the repeated stresses sustained by the sample. The cracks spread along the grain boundaries rich in aluminum. This hypothesis has been confirmed through an experiment performed by us under the following conditions:

A cupro-aluminum specimen with 9 percent aluminum has been maintained during 1500 hours in an apparatus in such a way that one of the specimen's faces was subjected to an oxidizing atmosphere (air plus SO_2) while the other face was cooled by water circulation. The average temperature was 500°. Stresses were applied onto the specimen throughout the entire test period. These stresses varied between 0 and 10 kg/mm².

Several observations were made:

(a) the alpha-eutectectoid structure of the sample gradually disappeared and was replaced by an entirely alpha structure which corresponds to the equilibrium structure. This transformation was completed on the hot face but not entirely completed on the cold face.

(b) The sample suffered an important dealuminization along the grain boundaries starting from the hot side. Dealuminization always proceeds cracking. Cracks begin along the dealuminized grain boundaries because such areas do not present any cohesion. Figure 1 shows the dealuminized grain boundaries and the crack's progression.

(c) The dealuminization never enters deeply inside the grains. This allows us to think, as the authors have suggested, that the grain boundaries are richer in aluminum than the centers. In the case of the cupro-aluminum (9 percent Al) specimen which is richer in aluminum than the authors' sample, the stress corrosion phenomenon takes the spectacular aspect of dealuminization.

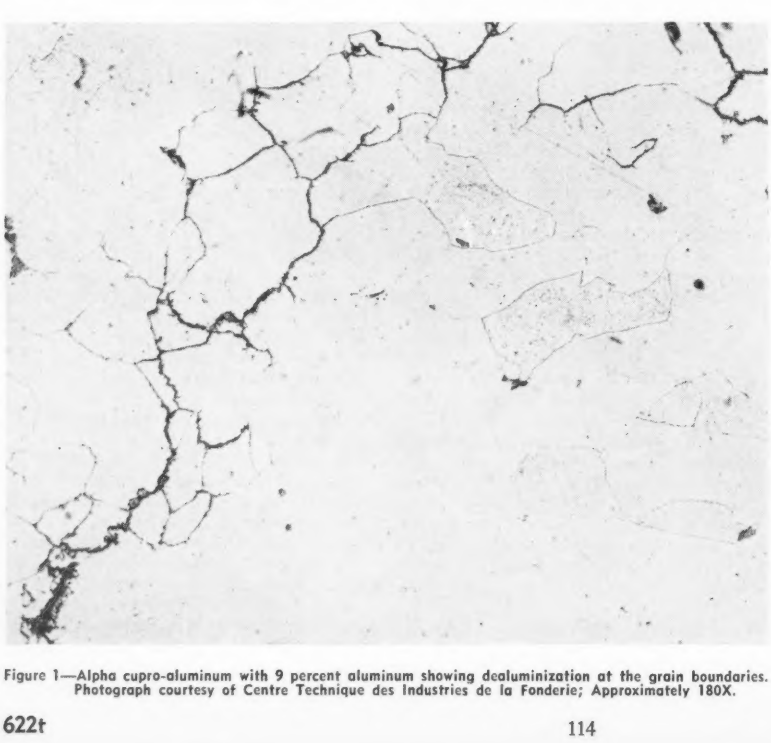

Figure 1—Alpha cupro-aluminum with 9 percent aluminum showing dealuminization at the grain boundaries. Photograph courtesy of Centre Technique des Industries de la Fonderie; Approximately 180X.

Equivalent Electrical Circuit Analogy Of Structure-to-Soil Potentials, By Roy O. Dean. Corrosion, Vol. 15, No. 11, 576t-580t (1959) Nov.

Comments by Annibale Pedrazzini, Societa Nazionale Metanodotti, Milan, Italy:

This article without doubt makes an important contribution to the problem of the correct measurement of pipe-to-soil potentials. However, I would appreciate a reply from the author on the following, as I differ from him on a few points.

On Page 40 (Figure 12A) the author states that the potential of the protected gas line with the reference electrode placed near the crossing was equal to +1660 mV. In this case we see (Figure 12B) that the total variation of potential would be equal to about 2.6 V (1.6 + 1).

The author also states that there is no interference because there was no change either in the reading of potential to a remote electrode or in the reading of span potentials (referred to 200 feet of pipeline).

In my opinion there was probably interference in this case. In fact the measure, referred to a remote electrode, cannot indicate any variation because it is placed out of the field due to the protective currents.

On the other hand, the current that leaves the gas line, owing to the interference, should be in this case very low because it is limited to a span not longer than 50 feet (Figure 12B) on which was observed the indicated positive potential. For instance if the coating resistance of the pipe is 3000 ohm m² the resistance to the ground of the span involved would come to about 3000/30 = 100 ohm.

If the real interference were equal to 1 volt, this would cause a dispersion of a current 1/100 = 0.01 Amp. This value could hardly be shown by means of span potential measurements also because this gas line is cathodically protected and therefore a current much higher than that calculated above probably flows through it.

In such cases, to see if we are really faced with interference problems, we place our reference electrode as near as possible to the structure which is supposed to have interference.

Reply by Roy O. Dean:

In the example Mr. Pedrazzini refers to, he is correct in saying that a few milliamperes of interference current flowing on the gas line could not be detected by the potential span measurement. However, it was found necessary to drain 31 amperes to the gas line in order to bring the pipe-to-soil potential of the gas line back to the value measured with the foreign cathodic protection rectifier off. This pipe-to-soil measurement was made with the reference electrode located directly over the gas line. If this is interpreted to mean that the interference current was 31 amperes, then it should have been detected by the potential span method since less than 155 milliamperes or one-half of one percent (0.5 percent) of 31 amperes could be easily detected on a 200 foot span of 34 inch pipe.

In order to further evaluate the possibility of cathodic interference at this pipe line crossing and at several other

similar locations, we have installed corrosion coupons. The coupons are 3 inch by 6 inch steel plates electrically connected to the gas main by a short piece of insulated 4/0 copper cable. These coupons were to be removed late this year.

The basic purpose of my paper was to stimulate additional research which is so badly needed on this controversial subject and to show the possible influence of anodic and cathodic fields in making cathodic protection measurements. The effect of these fields on the potential measurements may at times be on the reference electrode only, at other times on the underground structure independently, and sometimes may show a combined effect on both the reference electrode and the underground structure.

In my opinion, pipe line current measurements by the potential span method, or pipe-to-soil potential measurements to a remote reference electrode (an electrode placed completely out of the influence of all anodic and cathodic fields) are the most reliable means of determining interference.

Electrical Significance of Cathodic Protection on Hazardous Area Steel Docks, by T. A. Mullett and J. W. Johnstone, Jr. Corrosion, Vol. 16, 215t-220t (1960) May.

Comments by R. P. Howell and F. K. Scherer, Standard Oil Co. of California, San Francisco, California:

This article, in general, recommends the use of bonding cables between cathodic protected wharves and ships. It also recommends that the bond circuit be completed in an explosion-proof switch.

Although the authors have drawn upon considerable data, we do not believe that the evidence available supports these conclusions. For the following reasons, we conclude that bonding cables and explosion-proof switches should not be required for installations of this type:

1. Circuits that have low source potentials (for cathodically protected steel docks, the source potential would be the potential difference between the wharf and ship) require large circuit inductances to supply the additional energy required to produce ignition of hazardous vapors. As pointed out in the discussion below, there is not sufficient inductance in a typical bond cable installation to supply this additional energy.

2. Cargo hoses are normally made with a helical reinforcing wire spot-welded to a flange at each end. Therefore, each loading hose is a current path. Assuming that no bond cables are used, a calculation was made (see discussion below) based on separating the flanges of the cargo hose carrying the greatest current. The resultant energy was approximately 5 percent of the energy produced in the bond cable example discussed below.

3. Bond cables do lower the potential difference betwen dock and ship very slightly, but the decrease of potential difference is not great enough to justify using bond cables.

4. No sparks were observed at any time or at any location during field tests reported in article.

5. As far as it is known, there has never been a fire or explosion caused as a result of arcs or sparks occurring at cathodically protected steel docks.

As the use of bond cables does not prevent current flow through cargo hoses, a more positive method of eliminating the small amount of energy that is present when the flanges are separated would be to electrically isolate the ship from the wharf by installing insulation in all loading line risers. This is not considered necessary from the standpoint of safety.

As pointed out in the article, reference data are not available for circuits with potential sources below 4.0 volts. General trends are established, however. A general statement from an article by Allsop and Guenault[1] seems appropriate: "In circuits of high impedence, i.e., small current, it is impossible to satisfy the discharge relationship without an increase of voltage. This can only be got from the inductance in the circuit. Under these conditions, high inductance and small currents, the circuit voltage as Wheeler found is not of great importance."

From the typical example taken from the article under discussion, of 100 feet of 4/0 cable used as a bonding cable (50 feet coiled and 50 feet linear), the calculated inductance is so small (86.5 microhenrys) that only 4.3 millijoules of energy are available. This is about 71 percent of the energy that the article offers as a minimum ignition energy of hydrocarbon vapors for circuits that have smaller inductances than 0.001 henry and source potentials of less than 4.0 volts.

The low voltage source circuits found to exist at cathodically protected steel docks (order of magnitude of 0.5 volt), and the low inductance that exists in a typical bonding circuit, both tend to minimize or exclude the possibility of ignitions of hydrocarbon vapors. It is realized that the above general comments in no way prove that an explosion-proof switch is not required in the bonding circuit; only laboratory tests could do this. The type of circuit under investigation would be extremely hard to reconstruct in a laboratory. It is felt, however, that the results of the tests conducted at the Harbor Island Dock and all reference material that could be found tend to strengthen our company's policy of not requiring explosion-proof switches for bonding circuits.

As for the bonding cables being required at all, it should be remembered that current will flow in all possible parallel paths between the dock and the ship and that the only thing that can be accomplished by using bonding cables is to reduce the potential difference between the dock and ship at a faster rate because of the larger currents that would flow through the low resistance bond.

Assume, however, that no bond cable exists and that

$E = 0.5$ volt (this is more than twice the potential difference at Harbor Island Dock before connection of bond cables.)

$C =$ a constant (6 volts per centimeter in air)

$V = 3.3$ feet per second (a more realistic velocity of separating flanges)

$i_o = 10$ amps (this is based on the lowest hose resistance that was measured in the field tests)

Using the empirical formulas developed in the article, only 0.174 millijoules of arc energy is developed when the flanges are separated. The energy is below the minimum energy (0.24 millijoules) that is required to produce an ignition of hydrocarbon vapors by even a capacitance spark which is comparatively a point source of energy as compared to the large surface area that would exist in this case of flange faces.

We believe the foregoing considerations clearly indicate that bonding cables are not necessary between ships and cathodically-protected docks. To require such cables implies a hazard that does not exist and may cause unwarranted concern by operating people over the safety of these cathodic-protected installations.

References

1. G. Allsop and E. M. Guenault, The Incendivity of Electric Sparks in Relation to the Characteristics of the Circuit. Third Symposium on Combustion, Flame and Explosion. The Standing Committee on Combustion Symposia, pp 341-353, 1949, Baltimore, Maryland.

Reply by J. W. Johnstone, Jr.:

It was not the specific purpose of the article to recommend the use of bonding cables between cathodic protected wharves and ships. The purpose of the article was to examine a hazardous dock cathodic protection electrical installation as might and does exist, including bonding circuits, and basically to arrive at conclusions as to whether or not such a cathodic protection system at hazardous docks is or can be made safe.

We appreciate the fact that a difference of opinion exists in the industry as to whether or not petroleum cargo ships shall be bonded when at the dock. We have personally visited a dock on the West Coast where bonding was not practiced. Often local regulatory bodies dictate whether or not bonding is a required practice. The best technical reason for bonding which we can get from those who do bond or require bonding is that such a bond ties the ship and dock together for the elimination of a sudden surge high voltage potential between ship and dock which might occur due to pick-up on the pipeline to the dock.

Since we do use a bonding circuit, we recognized this circuit as the lowest resistance path between ship and dock and hence the circuit which would pass the largest amount of current for the poten-

tial between ship and dock which exists due to cathodic protection. Therefore, if this circuit were to open while carrying current, exposing an electrical arc in a hazardous atmosphere, it would release the greatest amount of electrical energy as compared to other circuits and might cause an ignition. We examined the situation to determine what maximum current was safe in the bonding circuit. In addition we were concerned as to whether or not a bonding circuit would cause considerable current drain on the cathodic protection system due to the addition of the ship's hull electrically to the cathode (dock).

With regard to the use of an explosion-proof switch, we had used this type of enclosure in the past and continue to do so. If the dock area has a hazardous classification, any arcing device, by NEC, should be explosion-proof. In a technical sense, to interrupt the limited current which we allow in the bonding circuit, we are inclined to agree that an explosion-proof switch is not required. However, for a small investment, we are sure that we will not interrupt some stray current of larger magnitude which might get into the bonding circuit, with an enclosure that is not suitable for possible flammable atmospheres. In addition, we have had good experience using the explosion-proof switches in the corrosive atmosphere which is often present at docks.

We appreciate the comments of the authors of the discussion. Although it gets away from the subject of corrosion and cathodic protection, we would like to hear the reasons for no need of bonding circuits between ship and dock, other than the reasons cited in their discussion.

Inhibition of Corrosion of Hypereutectic Aluminum-Silicon Alloys in Antifreeze Solutions, by H. Lee Craig, Jr. and Patrick H. Woods. Corrosion, Vol. 16, 457t-460t (1960) Sep.

Question by Thomas R. Pritchett, Kaiser Aluminum Corp., Spokane, Washington:

In most of your studies, you used weight losses to evaluate inhibitor efficiency. Do you have any data based on pit depth as a means of evaluation?

Reply by H. Lee Craig, Jr.:

We did not observe any pitting attack on the samples discussed in this paper, with the single exception of the pitting probability test shown in Figure 8. Pit depths were not determined here, as the critical factor is simply whether or not a given small area develops a pit.

Comment by Matthias F. Kelley, Jr., Virginia-Carolina Chemical Corp., Richmond, Va.:

In connection with Mr. Pritchett's question, I would like to state that in our work done in cooperation with Reynolds Metals Company, pitting was observed. In our tests a different type of testing apparatus was used. We found though that inhibitor F mentioned in Dr. Craig's paper overcame this pitting tendency.

Question by W. L. Miller, New York Naval Shipyard, Brooklyn, New York:

What would be the effect of a chromate-trisodium phosphate inhibitor of about 0.1 percent in cooling water (without antifreeze) on silicon-aluminum alloys?

Reply by Patrick H. Woods:

We have no data on this inhibitor combination but feel the introduction of trisodium phosphate would be much too basic for aluminum regardless of alloying elements. A neutralized chromate-phosphate inhibitor (pH of 7) in cooling water should give satisfactory inhibition of alumnum.

Discussions of technical articles appear in the June and December issues only when they do not immediately follow the article to which they pertain. Discussions received from November through April will appear in the the June issue and those from May through October in the December issue.

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Some Observations on Protection of Steel by Tin, by E. L. Koehler

Corrosion Resistance of Electrolytic Tin Plate—Part 2: The Alloy-Tin Couple Test—Symposium on Corrosion of Iron and Tin

A New Research Tool, by G. G. Kamm, A. R. Willey, R. E. Beese and J. L. Krickl

Accelerated Corrosion Test for Tin Plate in Grapefruit Juice, by P. R. Carter and T. J. Butler

Influence on Behavior of Tin-Steel Couple of the Area of the Component, by S. C. Britton and K. Bright

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Influence of Reactor Radiation on Oxidation of Niobium, by J. V. Cathcart and F. W. Young, Jr.

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VOLUME 16

JANUARY THROUGH DECEMBER

1960

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TABLE 2

SYSTEM

LiOH [pH
NaOH
H_2O_2
NH_4 N
Al_2 [SO

H_2SO_4

H_3PO_4

HNO_3

ERRATA – CORROSION, Volumes 15 and 16

High Temperature Metal Deterioration In Atmospheres Containing Carbon-Monoxide and Hydrogen by W. B. Hoyt and R. H. Caughey. Corrosion, Vol. 15, No. 12, 627t-630t (1959) Dec.

On Page 629t, four captions line were incorrectly placed. Please make the following changes:

Caption line beginning "Figure 9" should read:

Figure 8—Cross section through block valve seat ring showing deterioration of hard facing, cobalt bearing trim used in a secondary preheater exchanger's hot transfer piping, exposed to feed gas conditions.

Caption line beginning "Figure 11" should read:

Figure 9—Photomicrograph of Type 310 stainless steel tubing's inside surface. Tubing was exposed to feed gas (1200 to 1300 F.) in a secondary preheater exchanger. Magnification 225X, Aqua Regia etch.

Caption line beginning "Figure 8" should read:

Figure 10—Photomicrographs of Type 310 stainless steel tubing exposed to feed gas (1200 to 1300 F) in a secondary preheater exchanger. Photo A is cross section, Magnification 5X, macro etched. Photo B is inside surface of tubing, microstructure, Magnification 45X, Aqua Regia etch.

Caption line beginning "Figure 10" should read:

Figure 11—Photomicrograph of Type 310 stainless steel plate lining surface microstructure. Lining was used as hot outlet header in a secondary preheater, exposed to feed gas at 1200 to 1300 F. Magnification 225X, Aqua Regia etch.

Application of Anodic Protection in the Chemical Industry, by D. A. Shock, O. L. Riggs and J. D. Sudbury. Corrosion, Vol. 16, 55t-58t (1960) Feb.

On Page 56t, substitute Table 2 reproduced below for the original Table 2.

TABLE 2—Current Density Requirements for 304 Stainless Steel in Different Chemical Environments

SYSTEM	Current Density μ Amps/In²	
	To Obtain	To Maintain
LiOH [pH of 9.5]	516	0.14
NaOH [20% Caustic]	30,000	64
H_2O_2	64	1.3
NH_4NO_3	580	5.1
$Al_2[SO_4]_3$	580	5.2
H_2SO_4 67% 75° F.	33,000	24.5
180° F.	193,000	78
H_3PO_4 115% 75° F.	0.1	0.001
180° F.	0.2	0.001
350° F.	416	14.0
HNO_3 80% 75° F.	16	0.2
180° F.	75	0.7

Selective Removal of Chromium From Type 304 Stainless Steel by Air-Contaminated Lithium, by R. E. Seebold, L. S. Birks and E. J. Brooks. Corrosion, Vol. 16, 468t-470t (1960) Sep.

On Page 468t, middle column, third paragraph, fifth line from bottom should read:

Cr^{+6} to yield a yellow solution. Further

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STRESS-CORROSION CRACKING OF AUSTENITIC CHROMIUM-NICKEL STAINLESS STEELS

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ASTM Special Technical Publication No. 264

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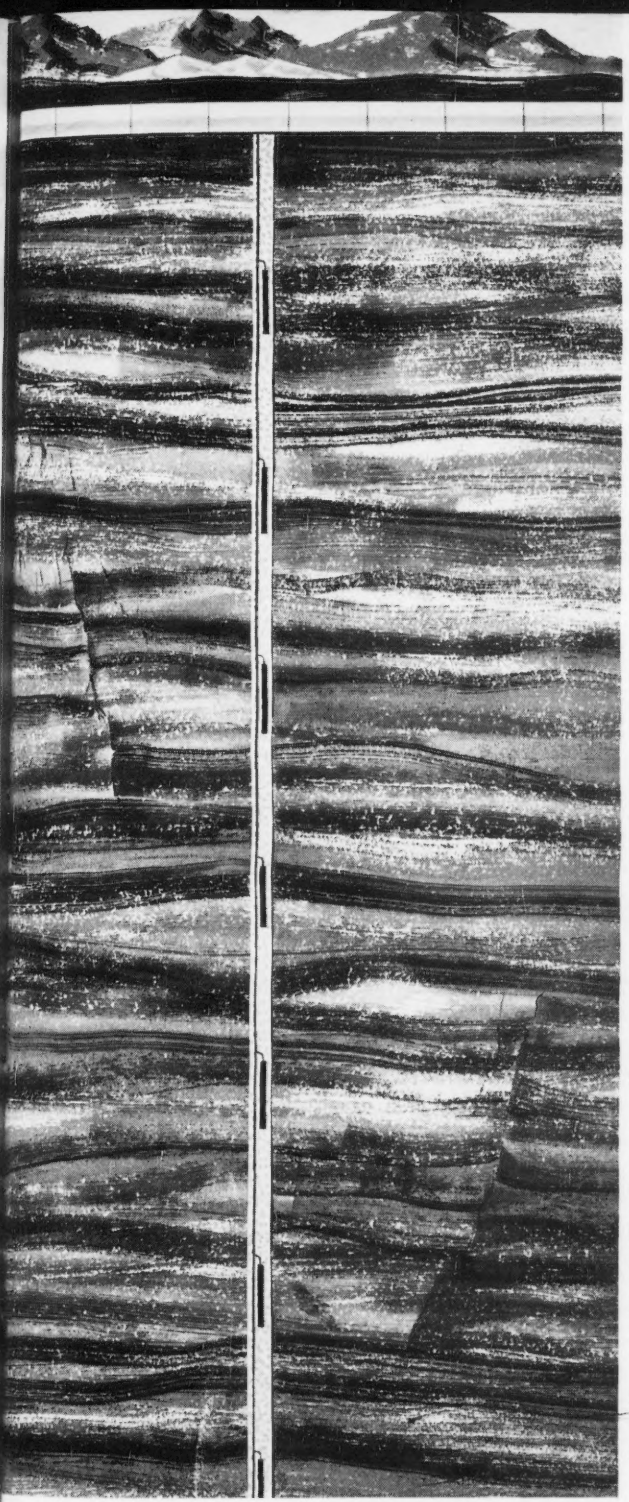

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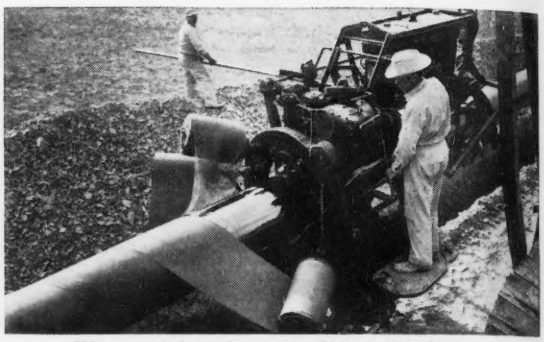
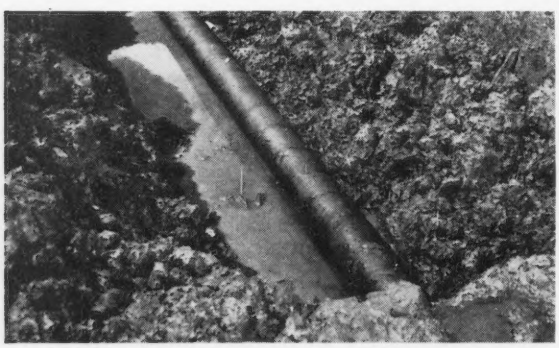
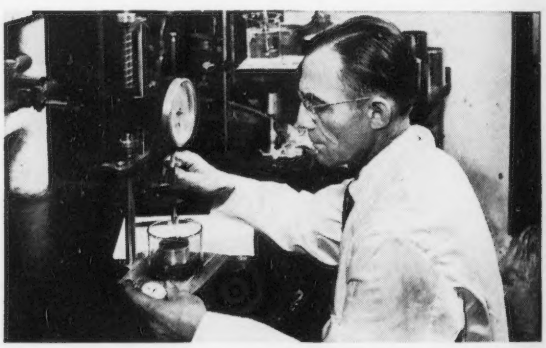
1 *During the next ten years, how much money will be invested in new domestic transmission facilities?*
(a) $3 billion; (b) $6 billion; (c) $16 billion.



2 *The cost of coal tar pipeline enamel amounts to what percentage of a pipeline's total cost?*
(a) 1½%; (b) 2½%; (c) 4%.



3 *This coal tar-protected pipeline, buried in salt water laden soil, was found in perfect condition after:*
(a) 12 years; (b) 17 years; (c) 23 years of service.



4 *What coal tar enamel manufacturer produces every drum of its pipeline enamel to written specifications?*

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